Guide to the Geology of the Cave in Rock and Rosiclare Area, Hardin County

David L. Reinertsen

Field Trip Guidebook 1992A April 25, 1992
Department of Energy and Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY

Cover photo of Cave-in-Rock by D. L. Reinertsen

Geological Science Field Trips The Educational Extension Unit of the Illinois State Geological Survey conducts four free tours each year to acquaint the public with the rocks, mineral resources, and landscapes of various regions of the state and the geological processes that have led to their origin. Each trip is an all-day excursion through one or more Illinois counties. Frequent stops are made to explore interesting phenomena, explain the processes that shape our environment, discuss principles of earth science, and collect rocks and fossils. People of all ages and interests are welcome. The trips are especially helpful to teachers who prepare earth science units. Grade school students are welcome, but each must be accompanied by a parent or guardian. High school science classes should be supervised by at least one adult for each ten students.

Lists of current year trips and guidebooks of earlier field trips for planning class tours and private outings may be obtained by contacting the Educational Extension Unit, Illinois State Geological Survey, Natural Resources Building, 615 East Peabody Drive, Champaign, IL 61820, (217) 244-2407 or 333-7372.

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ILLINOIS STATE GEOLOGICAL SURVEY
Morris W. Leighton, Chief

Natural Resources Building
615 East Peabody Drive
Champaign, IL 61820

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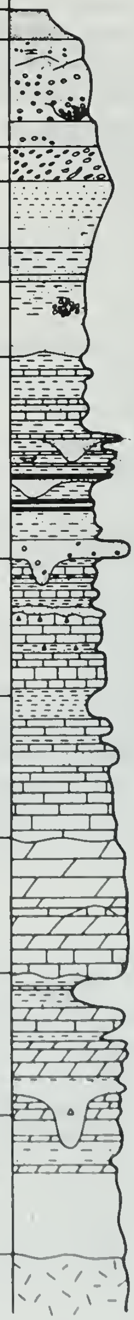
Era		Period or System and Thickness	Epoch	Age (years ago)	General Types of Rocks
CENOZOIC "Recent Life"	Age of Mammals	Quaternary 0-500'	Holocene	10,000	Recent—alluvium in river valleys
			Pleistocene Glacial Age	1.6 m.	Glacial till, glacial outwash, gravel, sand, silt, lake deposits of clay and silt, loess and sand dunes; covers nearly all of state except northwest corner and southern tip
		Tertiary 0-500'	Pliocene	5.3 m.	Chert gravel; present in northern, southern, and western Illinois
			Eocene	36.6 m. – 57.8 m.	Mostly micaceous sand with some silt and clay; present only in southern Illinois
			Paleocene	66.4 m.	Mostly clay, little sand; present only in southern Illinois
MESOZOIC "Middle Life"	Age of Reptiles	Cretaceous 0-300'		144 m. – 286 m.	Mostly sand, some thin beds of clay and, locally, gravel; present only in southern Illinois
PALEOZOIC "Ancient Life"	Age of Amphibians and Early Plants	Pennsylvanian 0-3,000' ("Coal Measures")		320 m.	Largely shale and sandstone with beds of coal, limestone, and clay
		Mississippian 0-3,500'		360 m.	Black and gray shale at base; middle zone of thick limestone that grades to siltstone, chert, and shale; upper zone of interbedded sandstone, shale, and limestone
	Age of Fishes	Devonian 0-1,500'		408 m.	Thick limestone, minor sandstones and shales; largely chert and cherty limestone in southern Illinois; black shale at top
	Age of Invertebrates	Silurian 0-1,000'		438 m.	Principally dolomite and limestone
		Ordovician 500-2,000'		505 m.	Largely dolomite and limestone but contains sandstone, shale, and siltstone formations
		Cambrian 1,500-3,000'		570 m.	Chiefly sandstones with some dolomite and shale, exposed only in small areas in north-central Illinois
ARCHEOZOIC and PROTEROZOIC					Igneous and metamorphic rocks, known in Illinois only from deep wells



Generalized geologic column showing succession of rocks in Illinois

CAVE IN ROCK AND ROSICLARE AREA

The landscape, geology, and mineral resources surrounding the towns of Cave in Rock and Rosiclare in extreme southeastern Illinois are the subjects of this field trip, which is sponsored by the Illinois State Geological Survey (ISGS). The area's rugged surface, one of the most scenic landscapes in the state, was formed mainly by differential erosion of Upper Mississippian and Lower Pennsylvanian sedimentary strata (see rock succession column on facing page) consisting of regular alternations of sandstone, limestone, and shale. Ridges are underlain by resistant rocks, usually sandstones, and valleys are underlain by relatively softer limestones and shales. Numerous faults cut the strata and interrupt the regularity of the ridges and valleys.

The towns of Cave in Rock and Rosiclare lie approximately 305 miles south-southwest of Chicago, 180 miles south-southeast of Springfield, 140 miles southeast of East St. Louis, and 65 miles north-northeast of Cairo.

Structural and Depositional History

Precambrian Era The Hardin County area, like the rest of present-day Illinois, has undergone many changes through several billion years of geologic time. The oldest rocks beneath the field trip area belong to the ancient Precambrian (Archeozoic and Proterozoic) basement complex. We know relatively little about these rocks from direct observations because they are not exposed at the surface anywhere in Illinois. Only about 30 holes have been drilled deep enough in our state for geologists to collect samples from Precambrian rocks; depths range from 2,100 to 5,400 feet in northern Illinois and from 13,000 to more than 17,000 feet in southern Illinois. From these samples, however, we know that the ancient rocks consist mostly of granitic and possibly metamorphic, crystalline rocks that formed about 1.5 to 1.0 billion years ago when molten igneous materials slowly solidified within the earth. By about 0.6 billion years ago, deep weathering and erosion had exposed the ancient rocks at the surface, forming a landscape probably quite similar to part of the present-day Missouri Ozarks. We have no rock record in Illinois for the long interval of weathering and erosion that lasted from the time Precambrian rocks were formed until Cambrian sediments were deposited across the older land surface; that interval, however, is longer than recorded geologic time from the Cambrian to the present.

Geologists seldom see Precambrian rocks except as cuttings from drill holes, but they use various techniques to determine some of the characteristics of the basement complex. For example, surface mapping, measurements of Earth's gravitational and magnetic fields, and seismic records gathered for oil exploration and other research indicate that rift valleys similar to those in east Africa formed here in what is now southernmost Illinois during the late Precambrian Era and affected what later became the Kentucky-Illinois Fluorspar Mining District. In the midcontinent, these rift valleys are referred to as the Rough Creek Graben and the Reelfoot Rift (fig. 1). The midcontinental rift structures formed when plate tectonic movements (slow global deformation) began to rip apart an ancient Precambrian supercontinent that had formed earlier when various ancient landmasses came together. (Continental collision is going on today as the Indian subcontinent moves northward against Asia, lifting and folding the Himalayas.) The slow fragmentation of the Precambrian supercontinent eventually isolated a new landmass, called Laurasia, which included much of what is now the North American continent.

Near the end of the Precambrian Era and continuing until Late Cambrian time, about 570 million to 505 million years ago, tensional forces within the earth apparently caused block faulting and relatively rapid subsidence of the hilly landscape on a regional scale. This permitted the invasion of a shallow sea from the south and southwest.

Paleozoic Era During the Paleozoic Era, what is now southern Illinois continued to sink slowly and to accumulate sediments deposited in shallow seas that repeatedly covered the area. At least 15,000 feet of sedimentary strata accumulated during the 325 million years of the Paleozoic Era. These sediments, when compacted and hardened (indurated), and the underlying the

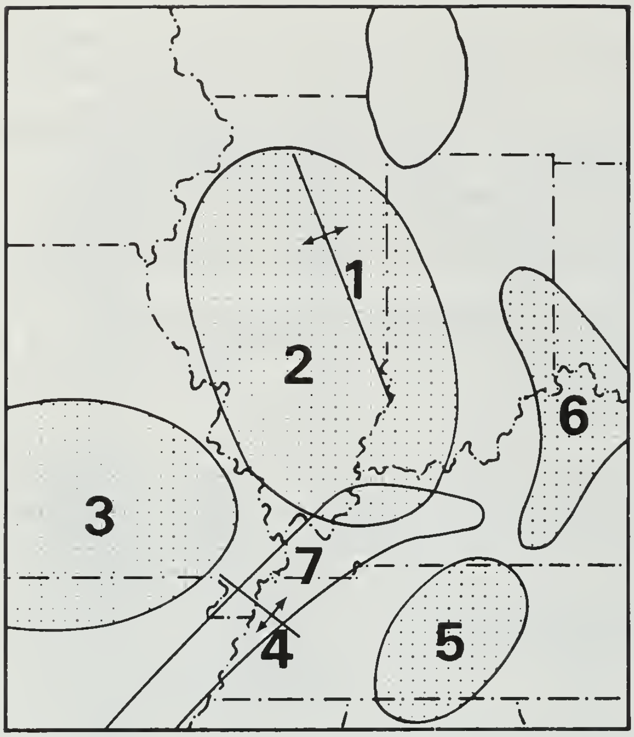


Figure 1 Location of some of the major structures in the Illinois region. (1) La Salle Anticlinal Belt, (2) Illinois Basin,(3) Ozark Dome, (4) Pascola Arch, (5) Nashville Dome, (6) Cincinnati Arch, and (7) Rough Creek Graben-Reelfoot Rift.

Precambrian rocks constitute the bedrock succession. Bedrock refers to the indurated rock units that underlie the soils or other relatively loose, crumbly, materials near Earth's surface.

In Hardin County, the field trip area may be underlain by about 13,000 feet of Paleozoic sedimentary strata, ranging from deeply buried rocks of Late Cambrian age (about 523 million years old) to surface exposures of Early Pennsylvanian age (about 315 million years old). From Middle Ordovician time about 460 million years ago, until the end of the Permian Period (and the Paleozoic Era) about 245 million years ago, the area that is now Illinois, Indiana, and western Kentucky, sank more slowly than it did earlier. Repeatedly, sediments poured into a broad trough or embayment covering the area, and spilled into surrounding areas as well. Because of compressive and stretching forces that developed at various times, Earth's thin crust has frequently been flexed and warped in various places. These recurrent movements occurring over millions of years caused the seas to drain from the region and, later, to slowly return. Periodically, sea floors were uplifted and exposed to weathering and erosion by rain, wind, and streams. Because some of the strata were eroded, not all geologic intervals are represented in the rock record. Figure 2 shows the succession of rock strata a drill bit would penetrate in this area if the rock record were complete and all the formations were present (the oldest strata are at the lower right and the youngest are at the upper left).

Formations, conformable contacts, and unconformities Sedimentary units, such as limestone, sandstone, shale, or combinations of these and other rock types are called formations. A formation is a persistent body of rocks that has easily recognizable top and bottom boundaries, is thick enough to be readily traceable in the field, and is sufficiently widespread to be represented on a map. Most formations have formal names, such as Renault Limestone or Downeys Bluff Limestone, which are usually derived from geographic names and predominant rock types. In cases where no single type is characteristic, the word formation becomes a part of the name. Many formations have conformable contacts where no significant interruptions took place in the deposition of the sediments that formed into rock units (fig. 2). In such instances, even though the composition and appearance of the rocks changes significantly at the contact between two

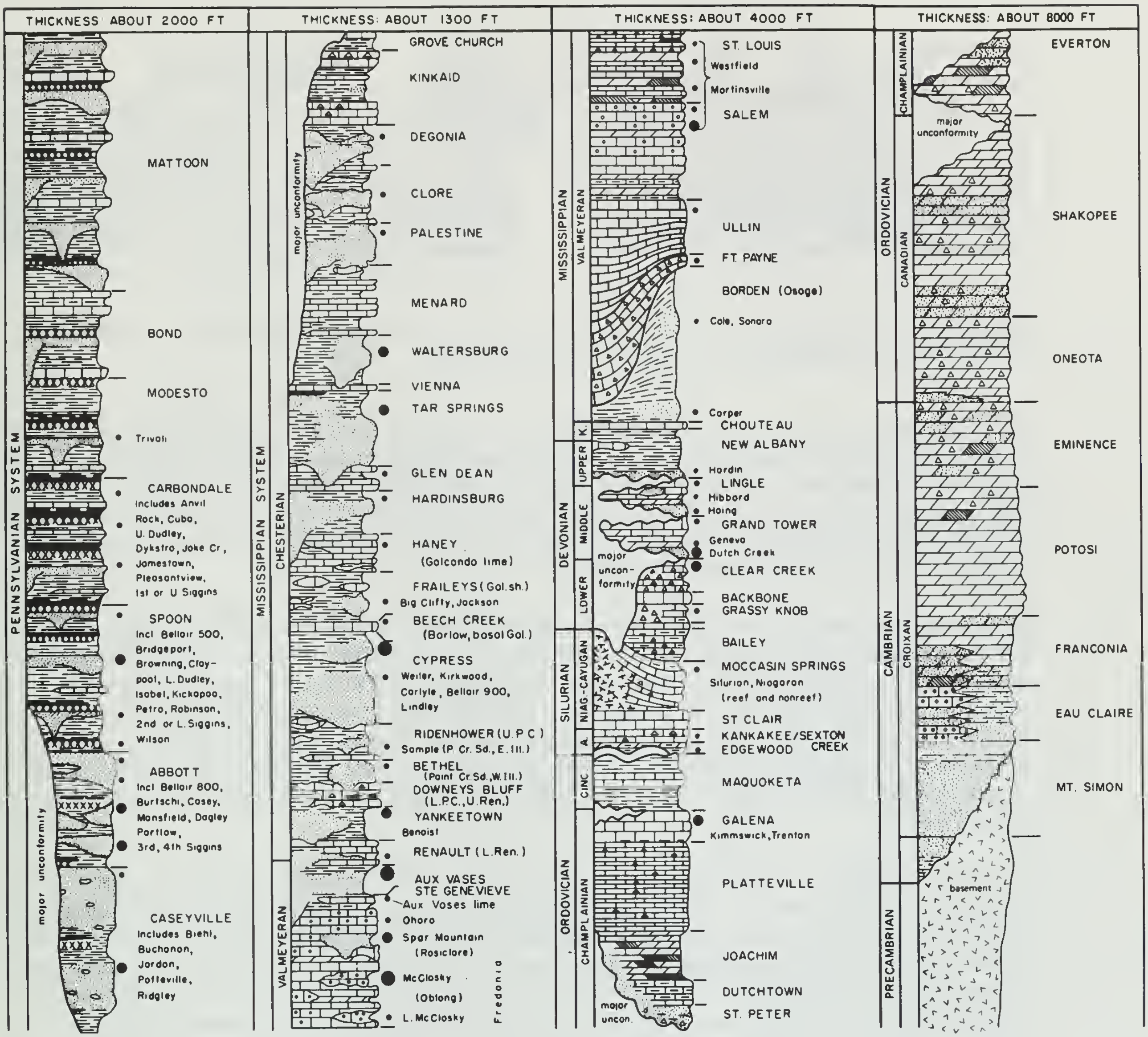


Figure 2 Generalized stratigraphic column of the southern part of the Illinois Basin. Black dots indicate oil and gas pay zones (variable vertical scale) (from Leighton et al. 1991).

formations, fossils in the rocks and the relationships between the rocks at the contact indicate that deposition was essentially continuous. At other contacts, however, the lower formation was subjected to weathering and at least partly eroded before the overlying formation was deposited. In these cases, the fossils and other evidence in the formations indicate the presence of a significant gap between the time when the lower unit was deposited and the time when the overlying unit was laid down. This type of contact is called an unconformity. Where the beds above and below an unconformity are essentially parallel, the unconformity is called a disconformity (fig. 3a); where the lower beds were tilted and eroded before the overlying beds were deposited, the contact is called an angular unconformity (fig. 3b). Major unconformities are indicated on the columns of figure 2; each represents a long interval of time during which a considerable thickness of rock, present in nearby regions, was either eroded or never deposited in parts of this area. Several smaller unconformities are also present. They represent shorter time intervals and thus smaller gaps in the depositional record.

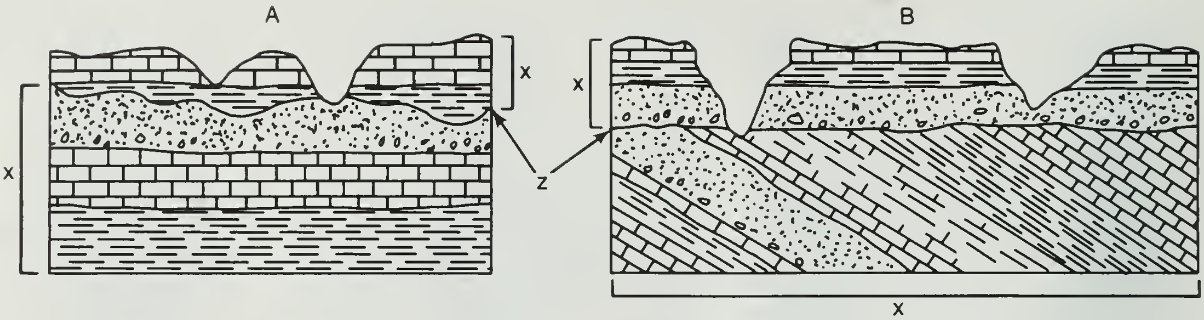


Figure 3 Schematic drawings of (A) a disconformity and (B) an angular unconformity (x represents the conformable rock sequence and z is the plane of unconformity).

Devonian Period The oldest rocks exposed in this area are Early Devonian limestones that formed from sediments deposited in the embayment that encompassed present-day Illinois about 390 million years ago. Erosion has left these rocks poorly exposed at the apex of Hicks Dome in west-northwestern Hardin County (figs. 4 and 5). Younger Devonian strata occur on the flanks of the structure. Some of these rocks have become silicified and cherty through the addition of silica from subterranean solutions.

Mississippian Period Relatively low-lying lands adjacent to the Illinois embayment generally did not contribute large volumes of sediment to the seas covering the region during Mississippian time, 360 to 320 million years ago. Early Mississippian shale and silty limestone are exposed around the flanks of Hicks Dome. Most of the sediment deposited during this time consisted of either locally precipitated carbonates or muds and sands eroded from areas far to the northeast; the muds and sands were transported here by a large river system probably similar in size to the Mississippi River. (A section detailing Mississippian Deposition is at the back of the guidebook).

Near the close of the Mississippian Period, gentle arching of the bedrock in eastern Illinois initiated the broad upwarp of the La Salle Anticlinal Belt (figs. 1 and 4). This belt is a complex structure consisting of smaller structures such as domes, anticlines (strata arched upward), and synclines (strata arched downward) superimposed on the broad, general upwarp. This gradual arching continued through the Pennsylvanian Period. Because the youngest Pennsylvanian strata are absent from the area of the anticlinal belt, either as a result of nondeposition or erosion, we cannot know just when movement along the belt ceased—perhaps by the end of the Pennsylvanian or a little later, during the Permian Period, the youngest rock system of the Paleozoic Era.

Pennsylvanian Period In the field trip area, Pennsylvanian-age bedrock strata consisting primarily of sandstone, siltstone, and shale, deposited as sediments in the trough's shallow seas and swamps between about 320 and 315 million years ago, are found beneath a relatively thin soil developed in windblown loess (pronounced "luss"). Resistant sandstones cap the prominent cliffs and ridges and are exposed in numerous streamcuts and roadcuts. Throughout a large part of Illinois, Pennsylvanian strata contain important coal resources. A description of these rocks and their occurrence may be found in Depositional History of the Pennsylvanian Rocks (at the back of the guidebook).

The thickness of Pennsylvanian strata is highly variable in the field trip area because these are the youngest bedrock strata present and the area has been highly faulted and eroded. This Pennsylvanian section, from the highest exposed strata down to the basal unconformity, is approximately 1,250 feet thick (Baxter et al. 1963), but only an aggregate thickness of about

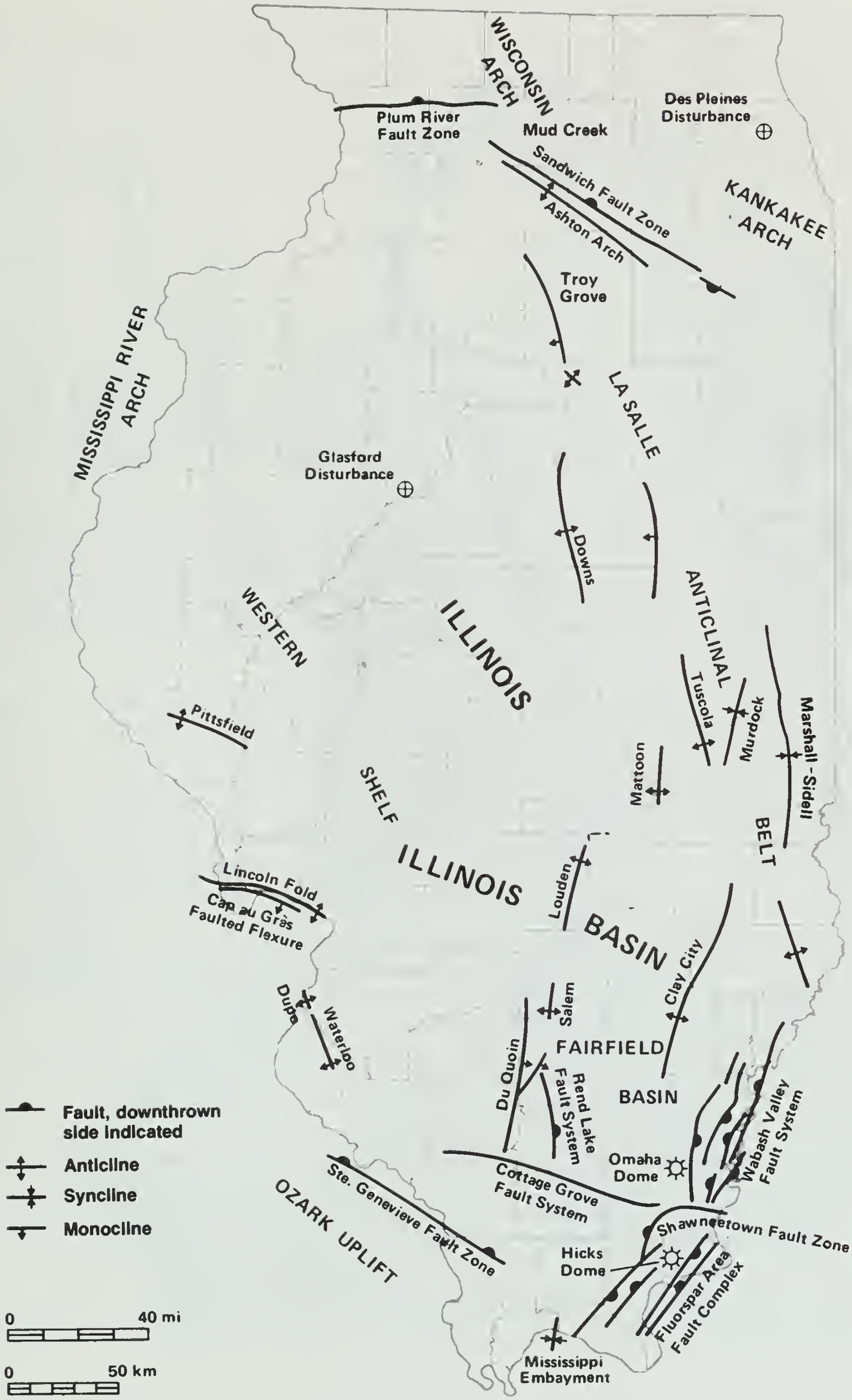


Figure 4 Structural features of Illinois.

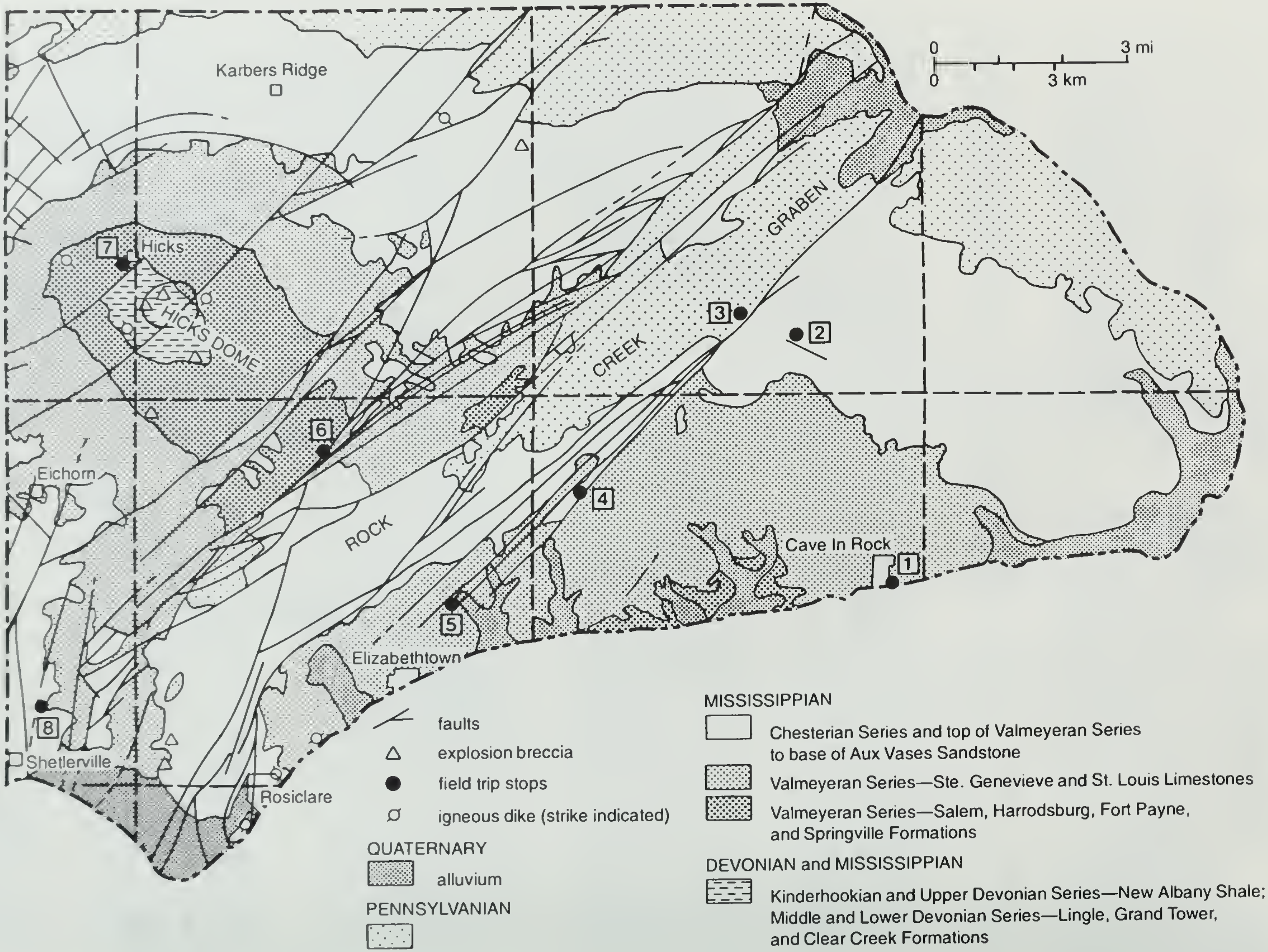


Figure 5 Surficial geology of Hardin County, Illinois.

600 feet of the section is exposed in outcrops. About 45 miles north in southeastern Wayne County, Pennsylvanian strata are more than 2,400 feet thick near the deepest part of the Illinois Basin. On the basis of evidence from outcrops and drill holes elsewhere in Illinois, geologists have concluded that the youngest rocks of latest Pennsylvanian and perhaps Permian age may have once covered some parts of what is now Illinois. Even younger rocks of Mesozoic and Cenozoic age also could have been present. On the basis of the degree of metamorphism (rank) of coal deposits and other indirect evidence, it is thought that latest Pennsylvanian and younger rocks as much as 1 mile thick once covered some parts of the state.

Regionally, the bedrock strata are tilted gently toward the northeast, although anomalous local dips are very common because of the great number of faults in the area. The area's major structural feature is Rock Creek Graben, an elongate downfaulted block extending diagonally across the area from northeast to southwest (fig. 5). Southeast of the Rock Creek Graben, the strata are cut by few faults in comparison to the complexly faulted strata within and to the northwest of the graben. A large area of these relatively unfaulted rocks, principally in the vicinity of Cave in Rock, exhibits markedly less rugged terrain than is found elsewhere in the field trip area. A rolling landscape with numerous sinkholes, characteristic of karst topography, has developed upon the thick middle Mississippian limestones occurring there.

Peridotite dikes and explosion breccias, apparently related in origin, also occur in the Cave in Rock and Rosiclare area; peridotite is a dark coarse-grained igneous rock of iron-magnesian minerals is formed deep within the earth. These features are believed to have formed during a period of intense crustal deformation when the strata were also broken by numerous faults. Radioactive dating of the igneous dikes has indicated a possible Permian age for their emplacement about 265 million years ago.

Mesozoic and Cenozoic Eras After the Paleozoic Era, during the Mesozoic Era, the rise of the Pascola Arch (fig. 1) in what is now southeastern Missouri and western Tennessee formed the Illinois Basin and separated it from other basins to the south. The Illinois Basin is a broad downwarp encompassing much of Illinois, southern Indiana, and western Kentucky (figs. 1 and 6). Development of the Pascola Arch in conjunction with the earlier sinking of deeper parts of the area gave the basin its present asymmetrical, spoon shape. The geologic map of Illinois (fig. 7) shows the distribution of various rock systems as they occur at the bedrock surface; that is, as if all glacial, windblown, and surface materials were removed.

During the Mesozoic and part of the Cenozoic Eras, a span of some 243 million years, and before the start of glaciation 1 to 2 million years ago, the ancient Illinois land surface was exposed to long, intense weathering and erosion. All rocks except those of Precambrian age were subjected to erosion during this time when possibly as much as several thousand feet of post-Pennsylvanian bedrock strata were erased by erosion. This erosion produced a series of deep valley systems carved into the gently tilted bedrock formations.

Glacial History Beginning about 1.6 million years ago, during the Pleistocene Epoch, massive sheets of ice—continental glaciers—hundreds of feet thick flowed slowly southward from centers of snow and ice accumulation in the far north and covered parts of present-day Illinois several times (fig. 8). The surface topography was considerably subdued by the repeated advance and melting back of the glaciers, which scoured and scraped the old erosion surface, and affected all exposed bedrock. When the last of the continental glaciers finally melted away from the region that is now northeastern Illinois, about 13,500 years before the present, it left nonlithified deposits of till (sand, gravel, and silt) behind. Modern soils developed in these materials.

During the Illinoian glaciation, about 270,000 years before the present, North American continental glaciers reached their southernmost extent, advancing as far south as where the southern part of Lake of Egypt now lies in northern Johnson County, Illinois, about 42 miles

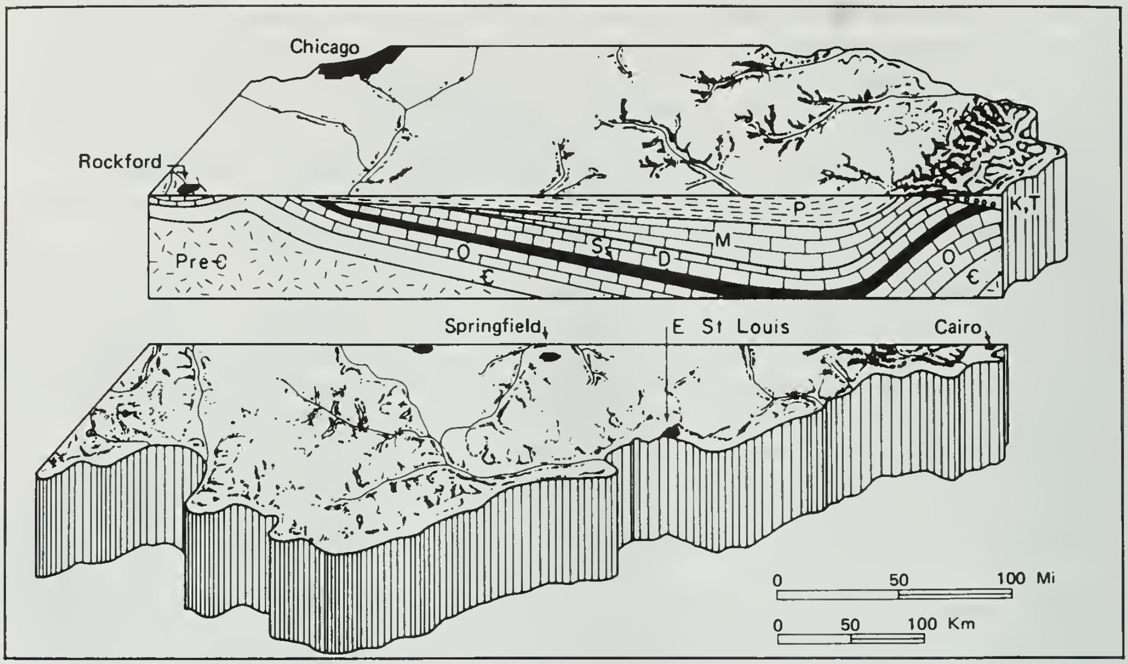


Figure 6 Stylized north-south cross section shows the structure of the Illinois Basin. To show detail, the thickness of the sedimentary rocks has been greatly exaggerated and younger, unconsolidated surface deposits have been eliminated. The oldest rocks are Precambrian (Pre-c) granites. They form a depression filled with layers of sedimentary rocks of various ages: Cambrian (C), Ordovician (O), Silurian (S), Devonian (D), Mississippian (M), Pennsylvanian (P), Cretaceous (K), and Tertiary (T). Scale is approximate.

west-northwest of Cave in Rock. The nearest location of materials deposited directly by the glaciers (till) is about 25 miles north-northwest, near Eldorado. Meltwater floods from the waning glaciers contributed to the deposition of clay, silt, sand, and gravel by the larger streams in parts of their lower courses (a process known as alluviation).

A cover of loess mantles the bedrock surface here. These fine-grained dust deposits of Illinoian and Wisconsinan age, which are 7 to 10 feet thick in the field trip area, are generally thicker closer to the Ohio River, where thick alluvial deposits were one of the major sources of the fine material.

Physiography A physiographic province is a region in which the relief and landforms differ markedly from those in adjacent regions. The area of Cave in Rock and Rosiclare lies in the easternmost part of the Shawnee Hills Section in Illinois. Physiographically, this westernmost part of the Interior Low Plateaus Province (fig. 9), is popularly referred to as the "Illinois Ozarks." The rugged terrain has resulted mainly from differential erosion of alternating sequences of resistant beds (sandstones) and less resistant strata (shales, limestones). Normally, erosion of these alternating layers of varied composition would produce a series of parallel ridges and valleys. Intense faulting and bending of the bedrock strata has resulted, however, in a complex pattern of stream dissection of an upland underlain by Mississippian and Pennsylvanian strata. The upland is maturely dissected, that is, there are only scattered remnants of a once widespread upland level. The terrain is mostly slopes produced by a profusion of younger streams (Leighton et al. 1948). The smaller streams have relatively short, steep longitudinal bottom profiles (gradients) and narrow, steep walls that appear V-shaped in cross section. The larger streams generally have somewhat wider alluviated valleys.

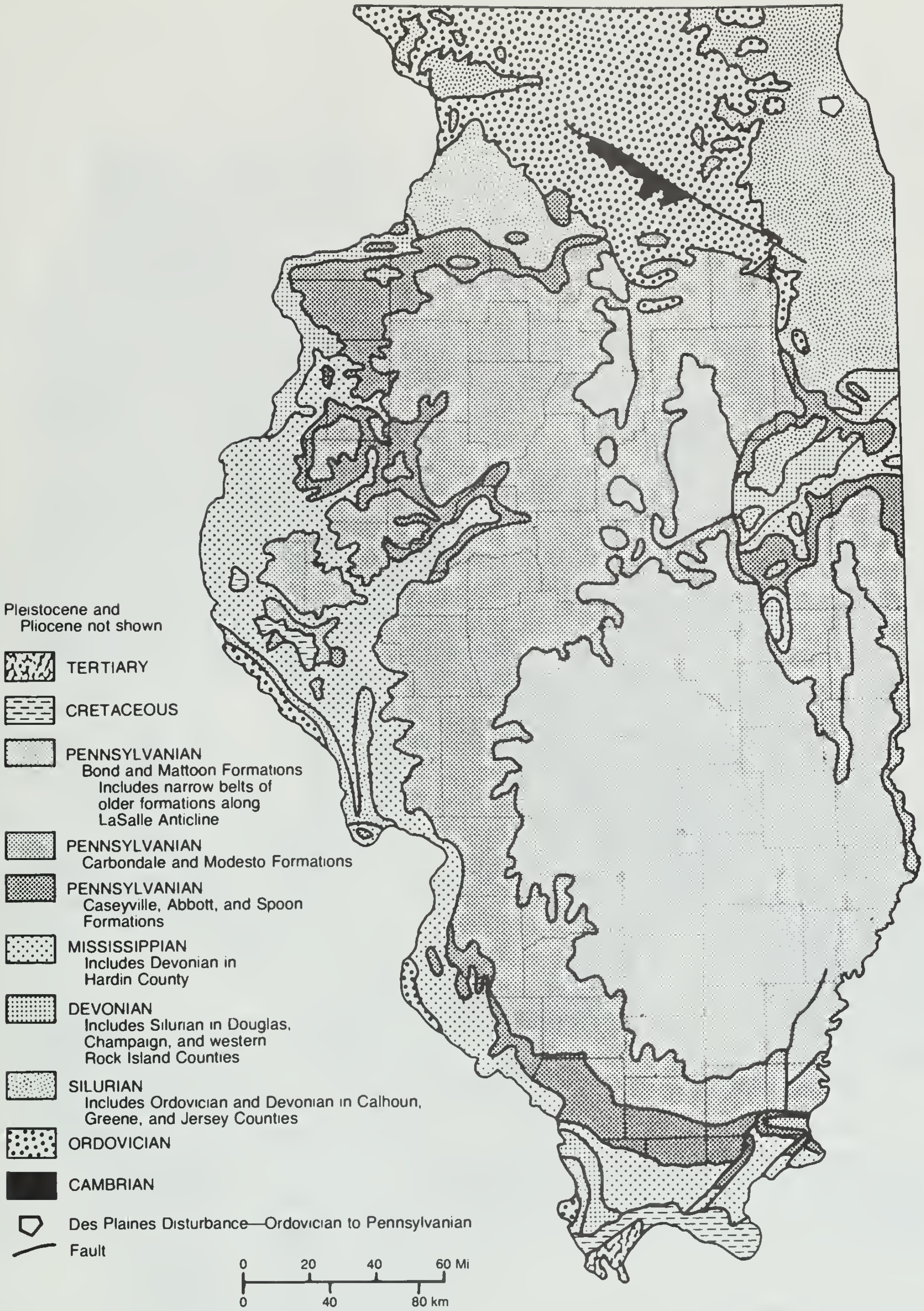


Figure 7 Bedrock geology beneath surficial deposits in Illinois.

Drainage The present-day drainage system is relatively complete. The larger streams have broad valleys and low gradients in their lower courses; the uplands generally have fairly good natural drainage. The eastern part of the field trip area is drained by Honey Creek and several of its tributaries. The northeastern part is drained by tributaries to Rock Creek, which in turn flows into Saline River about 2 miles before the Saline empties into the Ohio River. Peters, Hosick, Hogthief, Goose, and Big Creeks are larger streams draining much of the central part

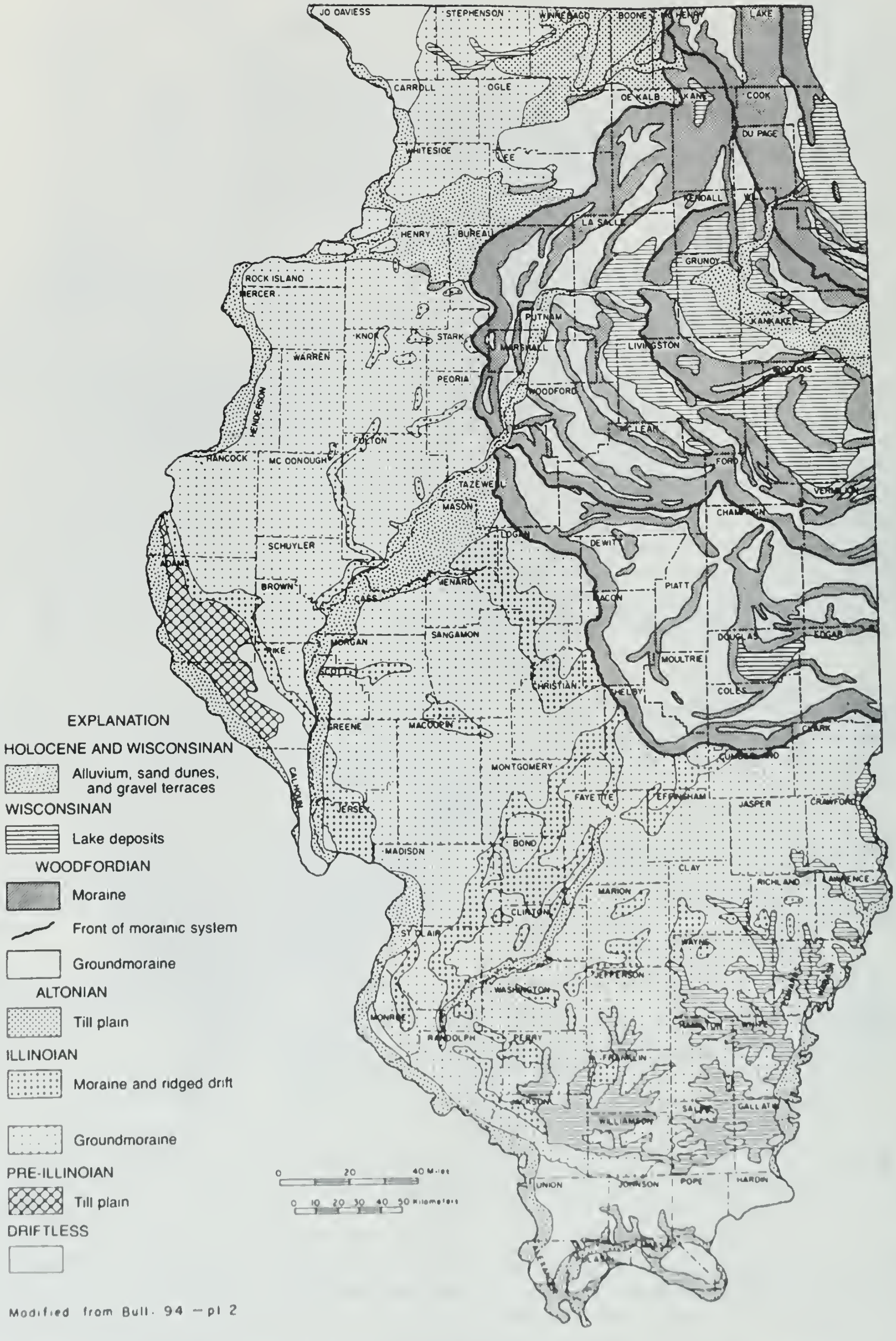


Figure 8 Generalized map of glacial deposits in Illinois (modified from Willman and Frye 1970).

of the area. A large number of smaller tributaries to the creeks and to the Ohio River also drain the area. The western part of the area is drained by Pinhook, Bucks, and Hobbs Creeks and Hicks Branch; all are tributaries to Big Grand Pierre Creek flowing south to the Ohio.

Relief The highest land surface the field-trip route will cross is 795 feet above mean sea level (msl) elevation at Stop 3. The highest surface elevation in the field trip area is slightly more than 820 feet msl, located about 2.5 miles southwest of Stop 3 The lowest elevation is 310 feet msl, the normal pool elevation of the Ohio River. The surface relief of the field trip route, calculated as the difference between the highest and lowest elevations, is 485 feet. The total relief for the area is slightly more than 510 feet. Local relief near cliffs may be as much as 200 feet in a few scattered locations.

MINERAL RESOURCES

Mineral Production

The field-trip route lies within the heart of the Illinois-Kentucky Fluorspar District. The Illinois portion of the district, with a history of fluorspar mining that dates from 1842, still has important deposits of minable fluorspar and its related minerals.

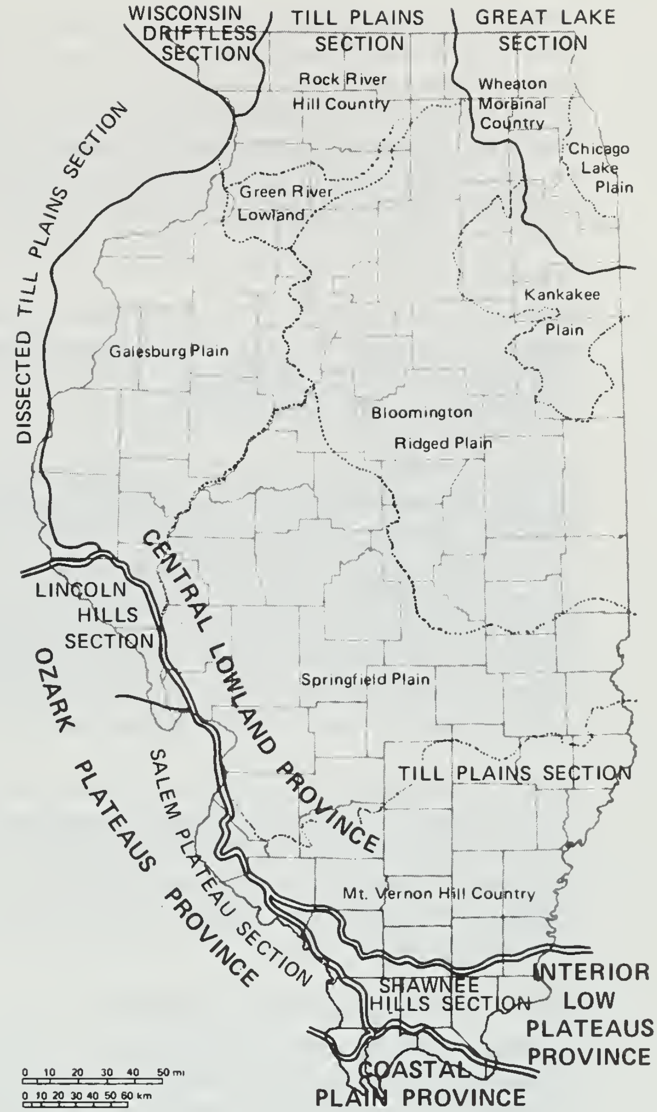


Figure 9 Physiographic divisions of Illinois.

Illinois remains the nation's largest producer of this mineral. Imports from foreign countries, such as Mexico, South Africa, China, and Canada, supply nearly 90% of U.S. needs. Illinois production figures are withheld to protect the confidentiality of the state's lone producer. Fluorite, calcium fluoride (CaF_2), was designated State mineral by the 74th General Assembly in July 1965. Fluorite, or fluorspar, is used in the smelting of steel and aluminum and in the production of hydrofluoric acid, the backbone of the fluorine chemical industry.

Among all counties in Illinois, Hardin County ranked 26th in 1989 in total value of minerals extracted—fluorspar, stone, zinc, lead, gemstones, sandstone, copper, barite, silver, and germanium. The stone that is produced here is used as agricultural lime, roadstone, riprap, and in the manufacture of cement. In addition, ground and crushed barite were also processed here. Of the 102 counties in Illinois, 98 reported mineral production during 1989, the last year for which complete records are available.

During 1989, $2.84 billion worth of minerals were extracted, processed and manufactured in Illinois, an increase of $35.3 million over the previous year.

During 1989, the value of extracted minerals in Illinois was $2.55 billion, an increase of 2.4% from 1988. Mineral fuels (coal, crude oil, and natural gas) made up 81.5% of the total value. Industrial and construction materials such as clay, fluorspar, sand and gravel, stone, and tripoli accounted for 18.2%. The remaining 0.3% came from metals such as lead, zinc, and silver, and from other minerals, such as peat and gemstones (Samson 1991). Illinois ranked 17th among the 50 states in total production of nonfuel minerals and continued to lead all other states in production of industrial sand, tripoli, and fluorspar.

Groundwater

Probably, few of us think of groundwater as a mineral resource when we consider the natural resource potential of an area. Yet the availability of groundwater is essential for orderly economic and community development. More than 48% of the state's 11 million citizens depend on groundwater for their water supply.

The source of groundwater in Illinois is precipitation that infiltrates into the soil and percolates into the groundwater system lying below the water table in the zone of saturation. Groundwater is stored in and transmitted through saturated earth materials called aquifers. An aquifer is any body of saturated earth materials that will yield sufficient water to serve as a water supply for some use. Pores and other void spaces in the earth materials of an aquifer must be permeable; that is, they must be large enough and interconnected so that water can overcome confining friction and move readily toward a point of discharge such as a well, spring, or seep. Generally, the water-yielding capacity of an aquifer can be evaluated by constructing wells into it. The wells are then pumped to determine the quantity and quality of groundwater available for use.

Thin sand and gravel deposits occur in a narrow band along the Ohio River in Hardin County, but the uplands are essentially bare of sand and gravel deposits that would yield water supplies. In the northern part of the county, thick Pennsylvanian sandstones at or near the surface may yield domestic water supplies. Most wells in the southern part of the county have been finished in the faulted and creviced middle Mississippian limestones that occur below the Chesterian surface rocks.

Future of Mineral Industries in Illinois

For many years, the mineral resources of the Midcontinent region have been instrumental in the development of our nation's economy. The mineral resource extraction and processing industries continue to play a prime role in our economy and in our lives, and will continue to do so into the future. The following paragraphs tell of recent initiatives involving the ISGS and mapping, especially in southern Illinois.

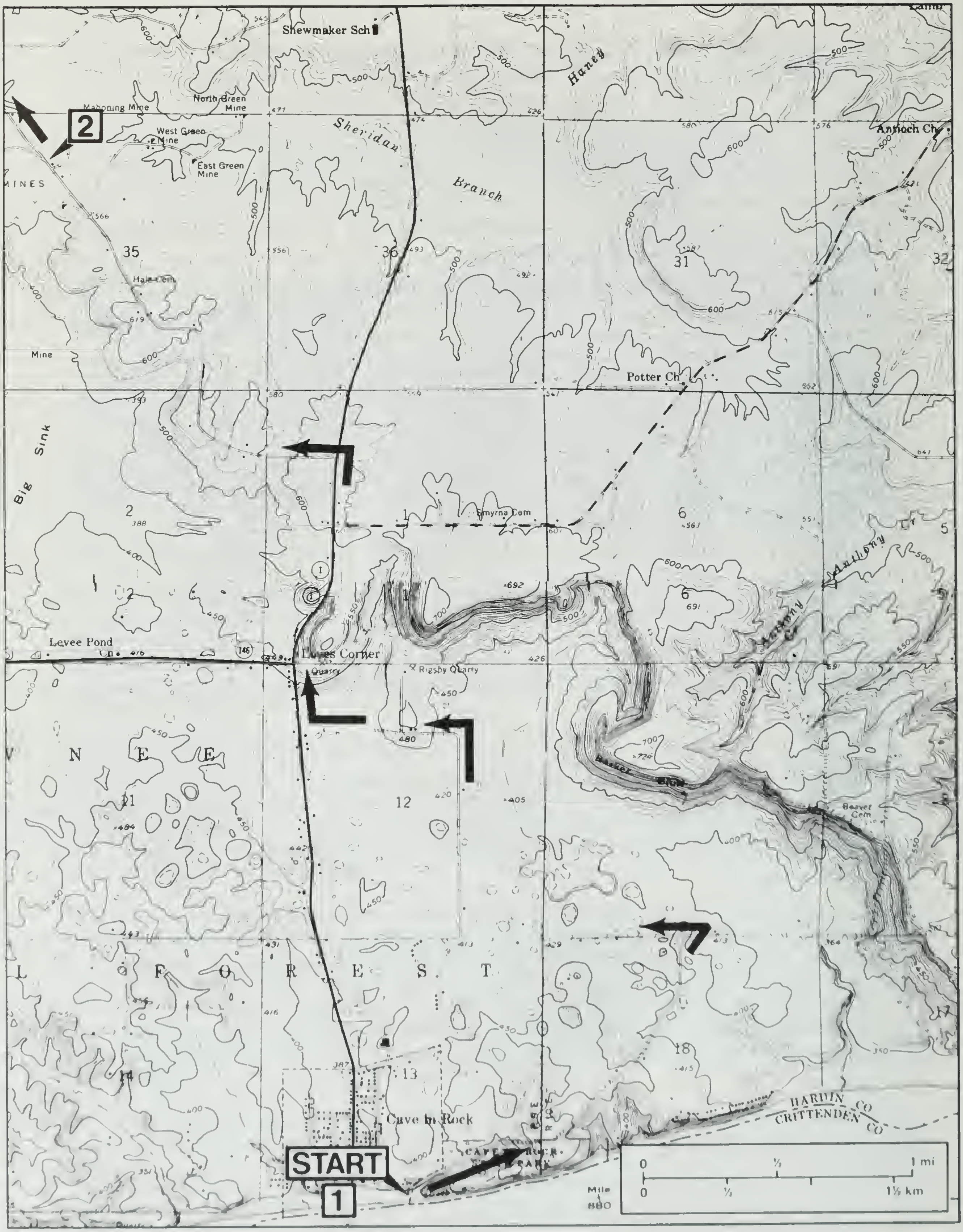
The prime mission of the ISGS is to map the geology and mineral resources of the state, conduct field mapping, collect basic geologic data in the field and in the laboratory, and interpret and compile these data on maps and in reports for use by the scientific community, industry, and the general public. Over the years, maps of the geology of the state have been published at various scales. Recently, more detailed maps and reports covering particular regions have been completed. To meet growing demands for detailed geologic information to guide economic development and environmental decision-making, the ISGS began a program to geologically map the 1,071 7.5-minute quadrangles of Illinois.

Geologic mapping of southern Illinois at the 1:24,000 scale (1 inch on the map equals nearly 0.4 mile on the ground) began with the Cave in Rock area (Baxter et al. 1963). This detailed mapping program led to a new understanding of the mineral potential for this area. In 1981, the ISGS resumed detailed mapping in southern Illinois with funding from the Nuclear Regulatory Commission (NRC). In 1984, mapping was continued with matching federal funds from the Cooperative Geologic Mapping Program (COGEOMAP) of the U.S. Geological Survey (USGS).

(More details are in Cooperative Geologic Mapping Program in Southern Illinois at the back of the guidebook.)

Recently, the U.S. Congress passed the National Geologic Mapping Act of 1991. This Act (H.R. 2763) authorizes a national program to map the geology of the United States in detail. Under the Act, the USGS will work with the 50 state geological surveys to coordinate and plan the program. Expenditures of up to $25 million annually will be matched by the states. In Illinois, similar authorizing legislation has been introduced in the General Assembly. If passed and fully funded at the state and federal levels, this program would result in completing the detailed geologic mapping of Illinois in about 20 years.

In 1975, the USGS began work on the quadrangle for Rolla, Missouri, under the Conterminous U.S. Mineral Assessment Program (CUSMAP). In 1987, the USGS continued this program for the adjacent Paducah 1° x 2° Quadrangle (scale of 1:250,000 or 0.25 in. = 1 mi). Because of the large area covered, this program involves the cooperative efforts of the USGS, ISGS, Kentucky Geological Survey, the Missouri Division of Geology and Land Survey, and the Indiana Geological Survey. (More details are in Mineral Assessment Program for Southern Illinois at the back of the guidebook.) In January 1992, a symposium on the Paducah CUSMAP and the Illinois Basin Consortium was held in St. Louis to present the results of the cooperative research programs. The results of these studies were presented in a USGS open-file collection of abstracts. (The preface from this volume, "Mineral Resources of the Illinois Basin in the Context of Basin Evolution," is at the back of the guidebook.)



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Smyrna Cem
Anthony Cr
Levee Pond
Lewes Corner
Quarry
Rigsby Quarry
Beaver Bluff
Beaver Cem
L O F O R E S T
Cave in Rock
HARDIN CO
CRITTENDEN CO
START
1
Mile 880
0 ½ 1 mi
0 ½ 1½ km

GUIDE TO THE ROUTE

Assemble at the lower parking area adjacent to the park entrance at Cave-in-Rock State Park (SW SW SE Sec. 13, T12S, R9E, 3rd P.M., Hardin County; Cave in Rock 7.5-Minute Quadrangle [37088D2]*). We'll start calculating mileage from the parking lot entrance.

You must travel in the caravan. Please drive with your headlights on while in the caravan. Drive safely but stay as close as you can to the car in front of you. Please obey all traffic signs unless the road crossing is protected by an emergency vehicle with flashing lights and flags. When we stop, park close to the car in front of you and turn off your lights.

Some stops on the field trip are on private property. The owners have graciously given us permission to visit their property on the day of the field trip only. Please conduct yourselves as guests and obey all instructions from the trip leaders. So that we may be welcome to return on future field trips, please do not litter or climb on fences. Leave all gates as you found them. These simple rules of courtesy also apply to public property. If you use this booklet for a field trip with your students, youth group, or family, you must, because of trespass laws and liability constraints, get permission from property owners or their agents before entering private property.

STOP 1 We'll view and study Cave-in-Rock. The entrance is just above the river and about 300 feet from the southeast corner of the parking lot (SE SW SW SE Sec. 13). Walk with care because footing may be poor, especially under wet or muddy conditions. You can walk up the hill on the road, and then walk down the stone steps to the main cave opening in the river bluff if you prefer.

The caves, subterranean caverns, and sinkholes created by groudwater dissolving limestone are solutional features typical of areas of karst topography, such as occurs in the vicinity of Cave in Rock (see route map). Cave-in-Rock is the largest and most famous cave in Illinois. (You'll notice we are using "Cave-in-Rock," as is the practice at Cave-in-Rock State Park. The town, however, is named "Cave in Rock," as is the 7.5-minute quadrangle.) The earliest known report about the cave was written in 1729 by a Frenchman who called it *Caverne dans le Roc* (Cave in the Rock). Based on this earlier report, Charlevoix located it on a map in his 1744 "History of New France." Some time after the Revolutionary War, the cave served as headquarters for outlaw bands that preyed upon hapless travelers on the Ohio River. The cave was used almost continuously by various criminal gangs until about 1834, when all outlaws had either been killed or discouraged from any further nefarious activities by the U.S. Government.

The cave has formed in Valmeyeran (middle Mississippian) St. Louis Limestone, which forms the bluff of the Ohio River in this vicinity. The great size of Cave-in-Rock gives us reason to believe that it once extended much farther to the south. Erosion by the Ohio River may have removed limestone that contained a larger cavern. The cave probably also extends much farther to the north than its rear wall, which is only about 100 feet from the mouth, and it probably plunges downwards beneath the mud floor at the back of the cave. A ravine in the park, just north of the ridge that contains the cave, has been cut down lower than the present floor of the cave. The cave must bend downward beneath the ravine bottom; otherwise, today's cave would simply be a tunnel through the ridge.

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* The number in brackets [37088D2] after the topographic map name is the code assigned to that map as part of the National Mapping Program. The state is divided into 1° blocks of latitude and longitude. The first two numbers refer to the latitude of the southeast corner of the block; the next three numbers designate the longitude. The blocks are divided into sixty-four 7.5-minute quadrangles; the letter refers to the east-west row from the bottom, and the last digit refers to the north-south column from the right.

Development of karst topography Karst topography develops in areas of fractured or jointed limestone bedrock where the strata are flat-lying or only gently tilted. There must also be ample rainfall and a level below the limestone upland, toward which groundwater can flow. Rainwater charged with carbon dioxide from the atmosphere and humic acids from decaying vegetation percolates downward through the jointed limestone. The water gradually dissolves the limestone and enlarges the joints to form an interconnecting network of subterranean fissures. More and more of the surface drainage will be diverted into the subsurface and, if enough time passes without a change in these conditions, some of the fissures will enlarge into great underground caverns such as the one at Cave-in-Rock State Park.

Sinkholes form wherever the roofs of caverns collapse. Other sinkholes are purely solutional features and form by the enlargement of joints from the surface downward. The result of this process is a rolling karst plain, pocked by numerous sinkholes and underlain by cavernous limestone. The area immediately surrounding the town of Cave in Rock possesses all of the conditions necessary for the development of karst topography. The area is underlain by a thick section of jointed Valmeyeran (middle Mississippian) limestones (Ste. Genevieve, St. Louis, and Salem), receives ample rainfall (probably more during Pleistocene time), and lies adjacent to the entrenched Ohio River, toward which subsurface upland drainage can move.

Theories of cave origin Two main theories have been offered by geologists to explain the formation of caves. The first is that caves are formed mainly above the water table (in the zone of unsaturated bedrock) by the scouring and solutional activity of groundwater (*vadose water*) flowing in subterranean streams. The second theory, more widely accepted by geologists, is that caves form mainly below the water table in the zone of saturated bedrock where groundwater (*phreatic water*) moves slowly under hydrostatic pressure. Recharge from the surface continually supplies fresh water that slowly dissolves the limestone and carries the calcium carbonate away in solution.

Both processes are probably active in the history of most caves: the latter being more important and occurring throughout most of the interval of cave formation, the former occurring at the end. Each case has to be evaluated individually.

Panno and Bourcier (1990) presented a hypothesis for the formation of caves and associated karst features near the southern margins of the Illinois, Michigan, and Appalachian Basins. They noted that the relationships between various features of these basins suggest that Pleistocene glaciations may have induced the discharge of saline waters from the basin margins. The great weight of the glaciers could have resulted in compaction of underlying sediments and in flushing of underlying aquifers as bottom melting of the glaciers occurred in recharge areas of basin aquifers. Pressure-induced upward migration of basin saline waters into near-surface strata caused the saline waters to mix with glacial meltwater and meteoric water and a dissolution of the limestone. Such dissolution would result in the development of horizontal caves and cave systems, and vertical phreatic conduits. Panno and Bourcier noted that, after cave formation, lowering of the water table and exposure of the caves to erosion results in further dissolution by vadose mechanisms.

Origin of Cave-in-Rock Evidence supporting the hypothesis that Cave-in-Rock was formed by phreatic water includes the fact that the rock floor of the cave apparently plunges below its present earthen floor. The rock floor at the mouth of the cave is actually higher than it is toward the back. Only groundwater moving upwards under a hydrostatic head (pressure differential) could produce such a feature. Scour features are virtually absent, and the only erosive feature attributable to the action of vadose water is the small central trench in the bottom of the cave.

The cave is not related in origin to the present sinkhole plain to the north, although it is tempting to consider the possibility that the cave connects with the bottom of Big Sink, the largest known sinkhole in Illinois. Evidence against a connection with Big Sink, or with the other

sinkholes, includes the fact that the cave is not presently serving as an outlet for groundwater discharge. The present sinkhole plain is probably too small to have supplied enough groundwater to form such a large cavern. The sinkhole plain is probably a Pleistocene feature that began to form less than 1 million years ago, and is still undergoing change as groundwater drains toward the Ohio River. Cave-in-Rock is much older than the Pleistocene. It may have been formed during Late Tertiary Time, probably late in the Pliocene Epoch, which lasted from about 10 million to perhaps 2 million years ago.

At one time during its formation, the cavern probably served as a major conduit for groundwater flowing southward from the highlands in the north. The cavern may have extended many miles southward to an ancient river, tributary to the ancestral Mississippi. However, there is no known evidence in Kentucky to substantiate its presence. The cave must have been slightly longer than it is now, and perhaps it simply discharged upwards as a great artesian spring somewhere south of here.

Miles to next point	Miles from start	
0.0	0.0	Leave Stop 1. CAUTION: cross traffic. TURN RIGHT (east) on the main road.
0.05+	0.05+	We are directly north of the cave.
0.5	0.55+	Entrance to the Cave-in-Rock Lodge is to the right. CONTINUE AHEAD (northeast).
0.15	0.7+	To the left is a large sinkhole containing water. You will note several other sinkholes, with and without water, on both sides of the road ahead.
0.75+	1.45+	To the left is a dry sinkhole. You can see rock in the deeper parts. The sinkhole appears to be very inviting for use as an illegal local dump.
0.05-	1.5+	CAUTION: unguarded T-road intersection. TURN LEFT (west). Many sinkholes are on both sides of the road in the next 0.8 mile; livestock use some of the water-filled ones. This area is part of the sinkhole plain mentioned at Stop 1.
0.8+	2.3+	CAUTION: unguarded T-road intersection on a curve; Missouri Portland and Golf Course Roads (500N, 1375E). The power substation at this intersection sits on the rim of a sinkhole. TURN RIGHT (north).
0.3	2.6+	Ahead is the large Rigsby-Barnard quarry operation.
0.45	3.05+	CURVE LEFT (west).
0.35+	3.45+	CAUTION: truck crossing at Rock Dust Products Road.
0.2	3.65+	STOP: 1-way at T-road intersection of Golf Course Road and State Route (SR) 1 (575N, 1310E). TURN RIGHT (north).
0.2+	3.9	Junction with SR 146 to the left. CONTINUE AHEAD (northward) up the hill.

0.35	4.25	MOVE LEFT into the center lane because you will turn left near the place where the passing lane disappears.
0.45+	4.7+	TURN LEFT (west) at T-intersection (675N, 1330E). A sign for Hardin County 1 Rt. 2.82 is also at the turn.
0.25	4.95+	To the left, you may catch a fleeting glance into a deep quarry.
0.5	5.45+	To the left is a view southwest into Big Sink. The bluffline scar in the distance is the quarry of the Hastie Trucking and Mining Company. You can see this when the foliage is off, but you may have trouble seeing it when the foliage is out.
0.75	6.2+	The fence openings on either side of the road are lanes that lead to abandoned fluorspar mines: Green Mines to the right and Mahoning Mines to the left. CONTINUE AHEAD (northwest). Quite a number of mines are in the area.
0.2+	6.4+	To the right is a lane leading to an abandoned Mahoning Mine. CONTINUE AHEAD (northwest).
0.05	6.45+	PARK along the roadside. CAUTION: beware of fast traffic. The gate on the other side of the main road is across the access road to another abandoned Mahoning Mine. The shaft headframe is still in place.

STOP 2 We'll discuss mining in the Southern Illinois Fluorspar District (SE NW SE NW Sec. 35, T11S, R9E, 3rd P.M., Hardin County; Saline Mines 7.5-Minute Quadrangle [37088E2]).

Illinois fluorspar Fluorspar, also called fluorite, consists of calcium (51%) and fluorine (49%). Chemically, it is known as calcium fluoride (CaF_2). It is a glassy mineral, commonly colorless, white, or gray, but much of it is some shade of purple; other colors include pink, blue, green, yellow, and tan. Crystals are characteristically cubic in form, but most fluorspar is massive, consisting of masses of interlocking crystals. The cubic crystals, often associated with crystals of calcite, galena, sphalerite, quartz, and other minerals, are found within pockets of deposits and are highly prized by mineral collectors.

The first reported use of Illinois fluorspar was in 1823. Fluorspar mined near Shawneetown, Illinois, was used to manufacture hydrofluoric acid (HF). In 11839, fluorspar and galena (PbS) were found in a water well sunk southwest of Rosiclare; however, the lead ore (galena) was of most interest. No active mining of lead ore took place in the Fluorspar District (fig. 10) until 1842, when a mine opened near Rosiclare. Although small tonnages of galena (the chief mineral sought in the Rosiclare area until 1870) were mined, large amounts of fluorspar associated with it were cast aside as waste. Many of these old waste dumps later served as valuable sources of fluorspar ore. Fluorspar is one of the more important mineral commodities in Illinois. Because only one company produces fluorspar in Illinois, production and value figures cannot be divulged. Fluorspar is also produced in Nevada. Nationally, production appears to have stabilized at about 70,000 tons, about half of what it was during the mid-1960s. Almost 90% of the fluorspar used in the United States is imported.

Illinois fluorspar occurs almost exclusively in Pope and Hardin Counties (fig. 10). The main production has come from the Rosiclare vein system (figs. 11 and 12) and from bedded replacement deposits (figs. 11 and 13) north of the Cave in Rock area. Less significant amounts of fluorspar have been mined from several areas outside these main areas.

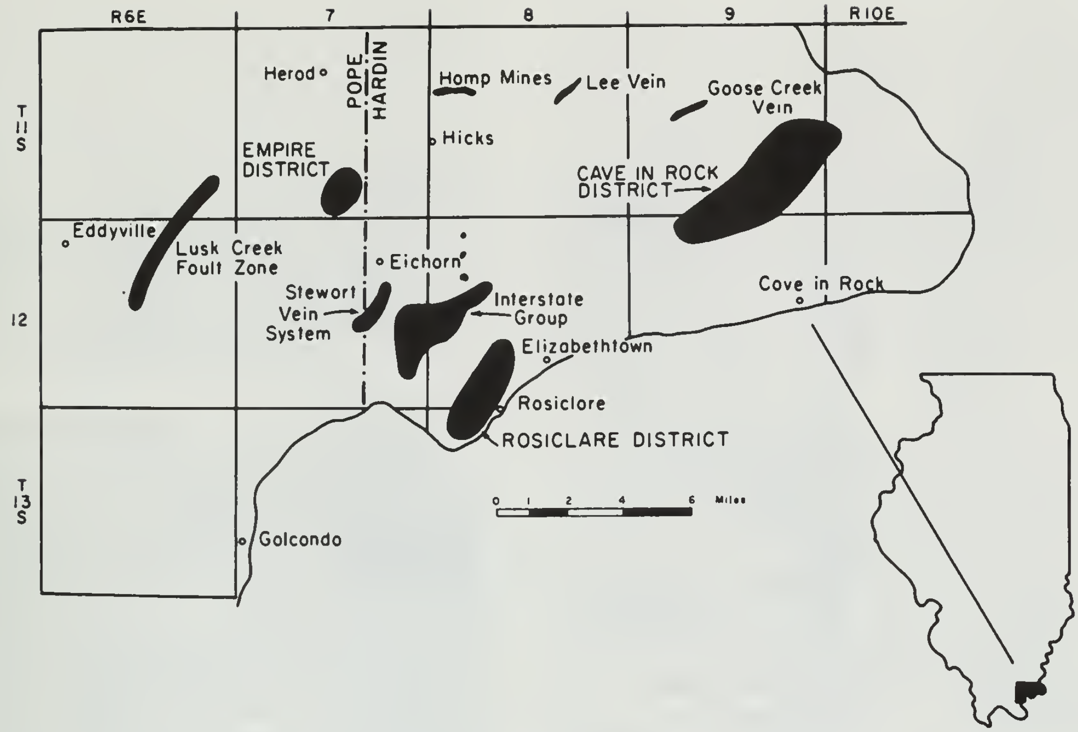


Figure 10 Principal fluorspar mining districts in the extreme southern Illinois region.

We are currently located in the Cave-in-Rock Mining District. The area about 1.25 miles southwest of here attracted the attention of early prospectors because ore cropped out on the hillside. The earliest mining began about 1900, and the chief producing years were between 1920 and 1937. The ores are of the bedded type (fig. 13) and occur at the top of the Mississippian (Valmeyeran) Ste. Genevieve Limestone in the Joppa Member (fig. 11), the chief horizon of bedded fluorspar in the Illinois Fluorspar District. The Minerva Crystal Mine, about 0.6 mile southwest, also operated mainly in this horizon, as did the Ozark-Mahoning Hill Mine about 1.8 miles north-northeast. Because of the general northeastward dip of the strata, the Joppa Member in the Hill Mine occurs at a depth of about 900 feet.

The Joppa Member consists of gray, oölitic and fine-grained limestone, characterized by numerous shale partings. Immediately overlying the Joppa is the Rosiclare Sandstone Member of the Aux Vases Sandstone. Numerous cuts within the mined area show the Rosiclare to consist mainly of tightly cemented, gray or greenish gray, calcareous, fine-grained sandstone. The sandstone is massive to thin-bedded. A few feet of sandy, micaceous, greenish gray shale or siltstone occurs at the base of the lowest sandstone unit, immediately above the Joppa Limestone. The bedded ores occur just below the siltstone. Where overburden was not too thick, mining in this area was by the open-pit method, but adits (mine tunnels) were also driven horizontally into the hillsides.

Vein deposits Vein deposits occur in steeply inclined, sheet-like deposits as fissure fillings along faults (fig. 12). A fault is a fracture in the rocks along which relative movement of the opposite sides has taken place. The width and continuity of the vein deposits depend on the size of openings between the fault surfaces in which they were formed. Fault planes (surfaces) are rarely perfectly parallel. Usually, the rock surfaces on either side of a fault are wavy and irregular, preventing a good fit where one side of the fault plane rests against the other. These irregularities caused the opposite walls of the fault planes to be pushed apart, producing the openings in which the fluorspar veins were deposited by mineralizing solutions. As a result, the

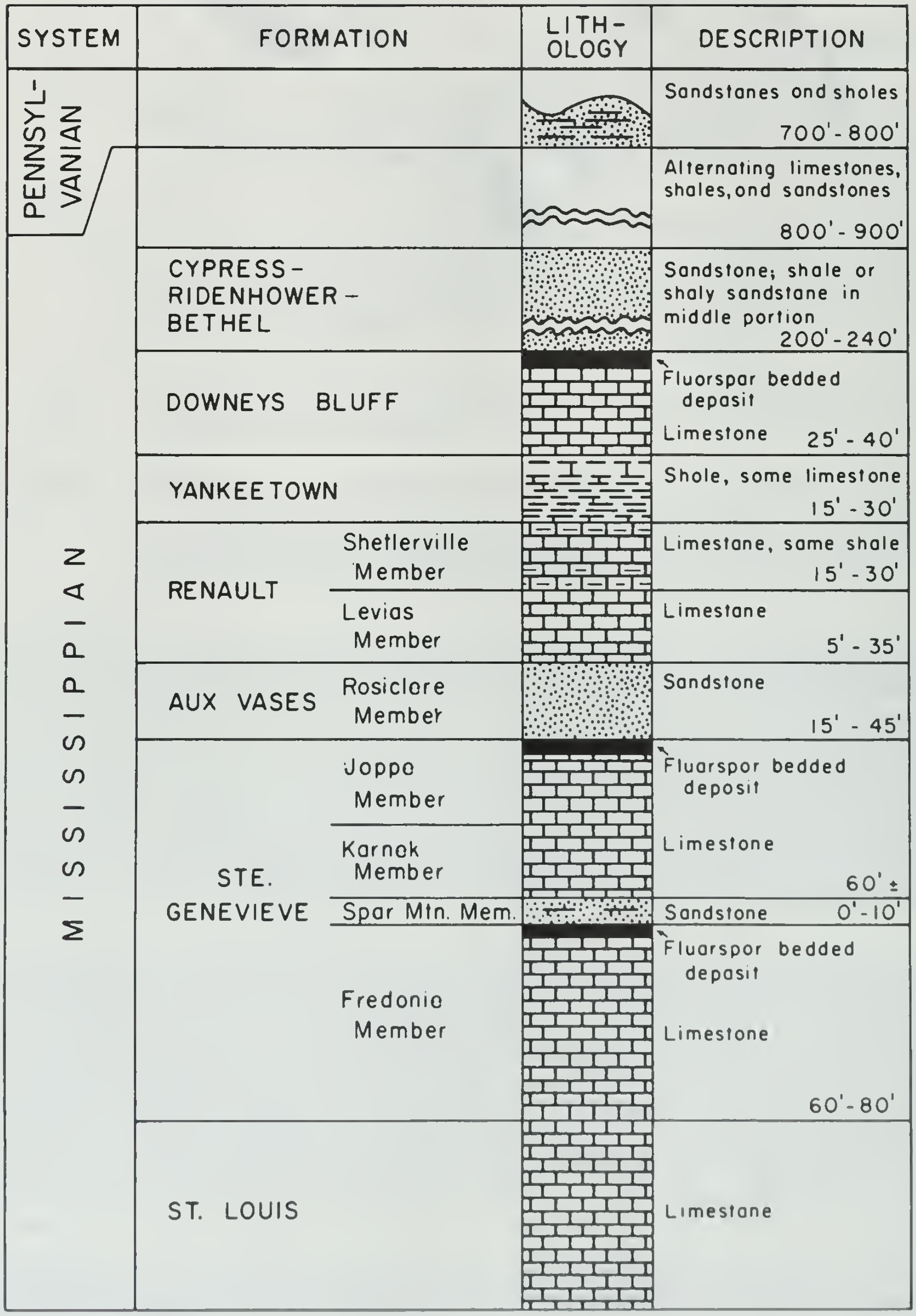


Figure 11 Principal fluorspar-bearing portion of stratigraphic column of the southeastern Illinois fluorspar district. Black bands represent horizons most favorable for the occurrence of bedded deposits. The most productive parts of the veins generally occur below the Rosiclare Sandstone.

veins pinch and swell both vertically and laterally. The veins range in thickness from a feather edge to as much as 30 feet. Suitable open spaces existed primarily along faults of moderate movement, commonly 100 to 200 feet. Smaller faults did not have large enough openings, and the grinding and crushing of the wallrock in larger faults did not permit openings to form. Vein deposits in the Rosiclare area have been mined at depths greater than 800 feet.

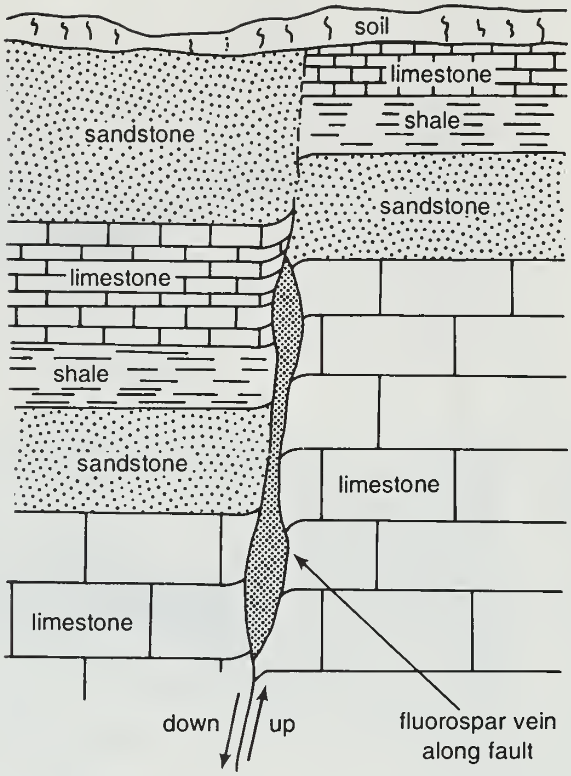


Figure 12 Diagrammatic cross section of fluorspar vein along a fault. The strata on the left side of the fault have moved downward with reference to those on the right.

Bedded deposits Bedded fluorspar ores are generally flat-lying, irregular bodies parallel to the bedding of the host limestones (fig. 13). Typically, the deposits are elongate and range from 200 to more than 2,500 feet in length and from 50 to 300 feet in width. They are commonly 4 to 15 feet thick and wedge out laterally. Unlike the vein deposits, in which the fluorspar simply filled open fissures, the bedded deposits were formed by a chemical reaction between the fluorine-bearing solutions and the limestone. The calcium carbonate of the limestone was changed to calcium fluoride or fluorite. The mineralizing solutions that formed the bedded deposits moved along minor faults and joint-like fractures that had little or no open space to permit deposition. Thus, the solutions spread out laterally along bedding planes within the limestone, perhaps even moving through the pore spaces in coarser-grained parts of the rock. This close contact with the limestone permitted the chemical reaction to take place. The exact origin of the mineralizing solutions that formed the vein and bedded ores is not known. Presumably, they were deposited by hot, fluorine-bearing, aqueous solutions rising from deep within the earth's crust.

Mixed deposits A few minable fluorspar deposits incorporate the features of both vein and bedded ores. In some vein deposits, certain limestone beds were selectively replaced short distances from the main fissure filling. Such mixed deposits are not common.

Relation to rock type Vein deposits are best developed in the stronger, more competent limestones and well-cemented sandstones in which adequate open spaces could be maintained along the faults. Weaker rocks, such as shales, sandstones, or shaly limestones, became crushed during faulting and generally filled rather than created openings. The best vein deposits are found in the relatively pure, competent Ste. Genevieve and St. Louis Limestones. Minable vein deposits also occur in competent younger rocks of the overlying Chesterian Series, but these ore bodies are limited in size and occurrence because shale beds associated with these strata generally plugged the faults.

The bedded replacement deposits occur chiefly within a relatively narrow stratigraphic interval from the base of the Bethel Sandstone, downward to the top of the Fredonia Member of the Ste. Genevieve Limestone (fig. 11). The principal deposits are found at three favored positions within this interval: at the top of the Downeys Bluff Limestone, the top of the Joppa Member of the Ste. Genevieve Limestone, and the top of the Fredonia Member of the Ste. Genevieve

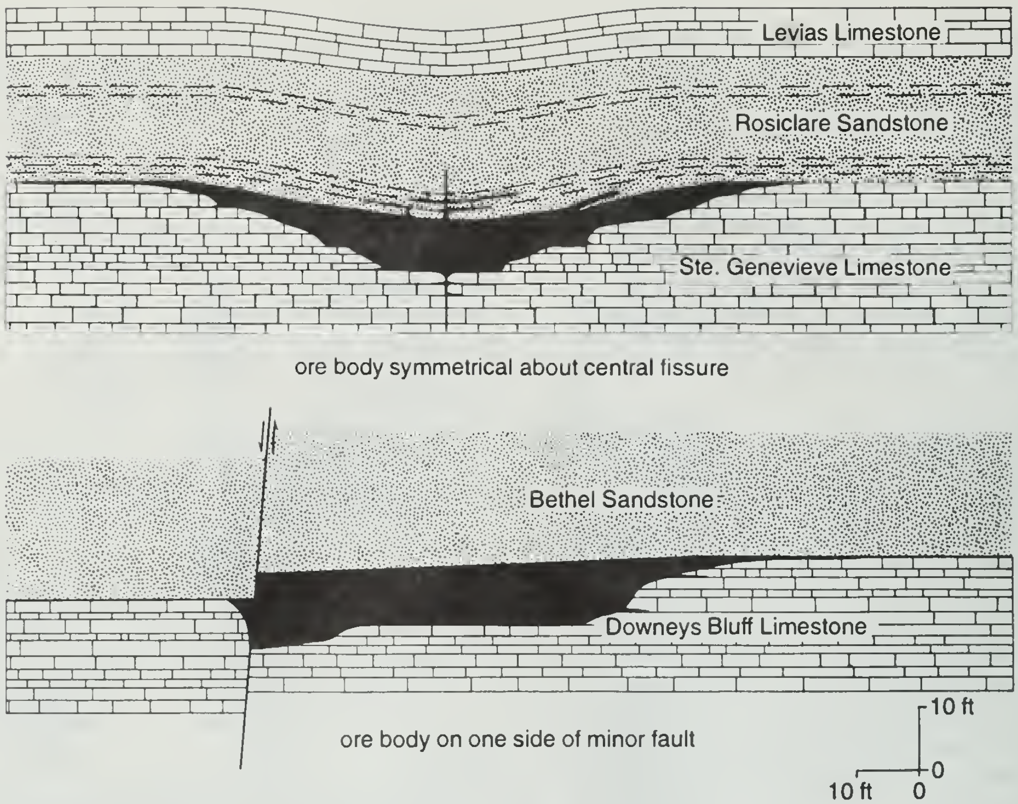
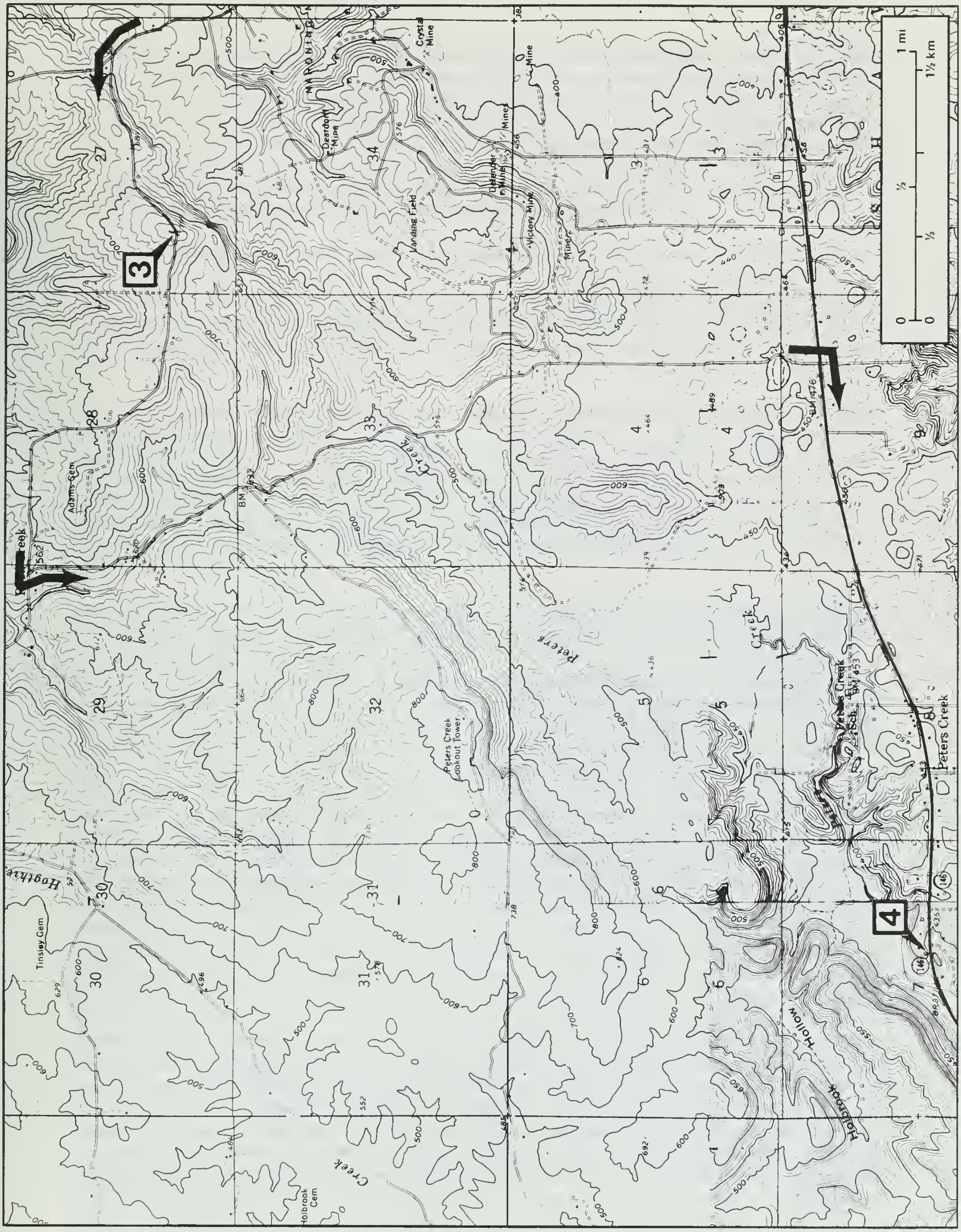


Figure 13 Schematic cross sections of two general types of bedding-replacement fluorspar deposits (adapted from Grogan 1949).

Limestone. Apparently, the limestone at these levels presented the most favorable conditions (purity, porosity, or fracturing) to allow replacement by fluorite. The lower mineralized zone near the level of the Spar Mountain Sandstone Member is commonly referred to as the "Sub-Rosiclare" zone. The heaviest mineralized portions of the two upper zones occur immediately beneath the Bethel and Aux Vases (Rosiclare) Sandstones. These sandstone units are usually tightly cemented, rendering them relatively impervious, which may have been a factor in limiting the upward movement of the mineralizing solutions.

Mineralogy Fluorspar (CaF_2) and calcite ($CaCO_3$) are the two chief minerals present in the vein deposits. Minor amounts of galena (PbS,) sphalerite (ZnS), and barite ($BaSO_4$) also occur. In the bedded deposits, fluorite is the principal ore mineral, but galena and sphalerite occur locally. Bedded ores commonly consist of alternating bands of coarse- and fine-grained fluorspar. Some banded ores also consist of dark, fine-grained layers of fluorite, forming the so-called "coontail" spar. Rare or small amounts of strontianite, witherite, dolomite, pyrite, ankerite, chalcopyrite, malachite, marcasite, smithsonite, limonite, gypsum, aragonite, melanterite, stibnite, and sulfur have also been identified in the fluorspar deposits.

Industrial uses Space does not permit a discussion of the mining, milling, or processing of fluorspar ore. Likewise, only brief mention may be made of its uses in industry.Illinois fluorspar concentrate is marketed in three grades: acid (97% pure), ceramic (85–96% pure), and metallurgical (60–72% pure). More than 60% of the fluorspar consumed in the United States is used by the chemical industry in the manufacture of hydrofluoric acid, the basic chemical for almost all fluorine chemical processes. Fluorine chemicals are used in the manufacture of synthetic cryolite, refrigerants, aerosols, plastics, medicines, high-octane fuels, and a host of other products. The steel industry consumed about 20% of total production in the form of metallurgical



3
4
Adams Cem
Tinsley Cem
Holbrook Cem
Peters Creek Lookout Tower
Peters Creek
Landing Field
Victory Mine
Defender Mine
Deardorff Mine
Crystal Mine
Mines
Holbrook
Hollow
1 mi
1½ km

spar for use as a fluxing agent in steel smelting. In the ceramic industry, fluorspar is used as a flux and opacifier in the manufacture of special types of glass and enamels.

0.0	6.45+	Leave Stop 2 and CONTINUE AHEAD (northwest).
0.3+	6.8+	The abandoned T-road to the left used to give access to three shafts to the west; one was the Deardorff Mine. CONTINUE AHEAD (north).
0.15-	6.95	CAUTION: T-road from the right on the curve (825N,1200E). BEAR LEFT (northwest).
0.25	7.2	Y-intersection (845N,1185E). BEAR LEFT (west). Beyond this curve, you may get occasional glances of Big Sink to the left if the foliage is not too dense.
0.25	7.45	Notice the indiscriminate dumping on the left side of the road!
0.45+	7.9+	PARK along the roadside as far off the road as you safely can. A fence remnant that formerly surrounded a radio transmission tower of the Minerva Oil Company is on the south side of the road. Walk south about 100 yards to the cliff for a view of Big Sink. An exceptional view of the Pennsylvanian escarpment and Eagle Valley Syncline is to the north.

STOP 3 We'll view Big Sink and other features of the Fluorspar District (N/2 NE SW SW Sec. 27, T11S, R9E, 3rd P.M., Hardin County, Saline Mines 7.5-Minute Quadrangle [37088E2]).

The cliff at this stop affords a good view to the southeast of the Fluorspar District. You can see several sites of active and inactive mines. Big Sink, the main feature seen from here, is a broad, treeless, flat area. During extended heavy rainfalls, the sink floods and forms a lake. Beyond Big Sink is the Mississippian cuesta. This feature is a ridge with a gentle, north-sloping upper surface and a steep, southward-facing cliff or escarpment.

The bluff here is underlain by sandstone of the lower Pennsylvanian Caseyville Formation. The Caseyville Formation ranges from 250 to 350 feet thick. Two thick, massive sandstone units, the Battery Rock and the Pounds Sandstone Members, generally constitute more than half of the formation. Shale and thin-bedded sandstone make up the remaining portion. These massive sandstone units consist of fairly pure to slightly micaceous quartz sandstone that contains numerous white, rounded quartz pebbles. The sandstones resemble each other so closely that it is sometimes difficult to distinguish them. Although this area was recently mapped, ISGS geologists were not able to definitely identify the sandstone unit exposed here. It is probably the Pounds Sandstone.

The Caseyville sandstones are very resistant to erosion. As a result, wherever exposed, they are usually cliff-formers. They represent alluvial deposits that were laid down in the channels of an ancient Pennsylvanian river system, which flowed toward the southwest to the sea. Current structures, including ripple marks and crossbeds, are well-developed in the sandstones. You can see excellent examples of crossbedding by climbing part way down the bluff and looking at the cliff face. Inclined downwards toward the southwest, the crossbeds reflect the direction of current flow. The purity and relative coarseness of the sandstone suggest that the currents were swift.

The contact between the Pennsylvanian and underlying Mississippian strata in the Midcontinent is everywhere marked by a major erosion surface or unconformity. At the close of the Mississip-

pian Period, the sea had withdrawn from the region, and early Pennsylvanian rivers cut deeply into the upper Mississippian rocks. Later, during Pennsylvanian time (about 320 to 286 million years ago), the sea repeatedly advanced and retreated across the region. Many alternations of marine and nonmarine sandstones, shales, and limestones were deposited during this time. Much of the time, the region was a vast, swampy lowland bordering the sea. Great accumulations of peat formed in the swamps; the peat was later transformed into coal. Several minable coals occur in the Illinois Basin. Some of them are presently being mined several miles to the north in Gallatin County.

The Caseyville Sandstone exposed here occurs about 3 miles south of the main boundary of Pennsylvanian-aged rocks (figs. 1 and 5). The Caseyville Sandstone forms part of a tongue of Pennsylvanian rocks that is preserved in an elongate downfaulted block known as the Rock Creek Graben. A graben is a fault-bounded block that has dropped down relative to the blocks on either side (fig. 14). A similar, larger graben (Dixon Springs Graben) occurs to the west in Pope County (fig. 7).

The southeast side of Rock Creek Graben is bordered by Peters Creek Fault System. Here, the Peters Creek Fault is essentially a single fault passing along the base of the bluff. Toward the southwest, it splits into a number of branches. Total vertical displacement along the system is more than 1,000 feet. On the northwest side, the graben is bordered by the Hogthief and Goose Creek Fault Systems. These systems generally consist of several branching faults in a zone up to 0.5 mile wide. Maximum cumulative displacements along these faults range from about 1,600 feet along the Hogthief Creek Fault System to about 500 feet along the Goose Creek Fault System.

Although the central block is downthrown, the Caseyville sandstone forms prominent escarpments along the bordering faults. Locally, the central block stands as much as 300 feet above the adjacent terrain. This apparently anomalous condition is the result of differential erosion. After erosion had cut through the sandstone bounding the graben, the relatively softer Mississippian rocks, consisting largely of limestone and shale, were then eroded more rapidly than the sandstone within the graben.

Origin of the faults The exact cause of the complex faulting is not known. At the end of Pennsylvanian time, or during early Permian time (about 260 million years ago), the Paleozoic strata of the present Illinois-Kentucky Fluorspar District may have been arched into a northwest-trending, elongate dome by an enormous rising body of magma (molten rock) generated at great depth. Tensional fractures were formed parallel to the long axis of the dome because of the stretching of the sedimentary strata. Some magma was squeezed into these fractures to form the dark igneous dikes now exposed at the surface in southeastern Illinois and western Kentucky.

After the magma had begun to crystallize and ceased to push upwards, the area was broken by a second set of fractures, oriented northeast-southwest, probably by forces related to those that were forming the Appalachian Mountains along the eastern margin of the continent. Relaxation of these forces, plus shrinkage of the body of magma as it continued to cool, caused the domed area to collapse into a series of blocks bounded by the northeast-trending fractures. The resulting normal faults trended northeast-southwest and became the channelways for the fluorine-bearing solutions that were probably derived from the underlying magma body. These same faults also served as sites of deposition for the fluorite vein deposits. Most of the faults are normal, with fault planes inclined at high angles (70° to 80°) but some are reverse faults (fig. 14). Movement along the faults was largely vertical, but in some places, there was also horizontal (sideways) movement. The Shawneetown Fault Zone, a large faulted structure in Gallatin and Saline Counties just north of the Fluorspar District, shows evidence of reverse

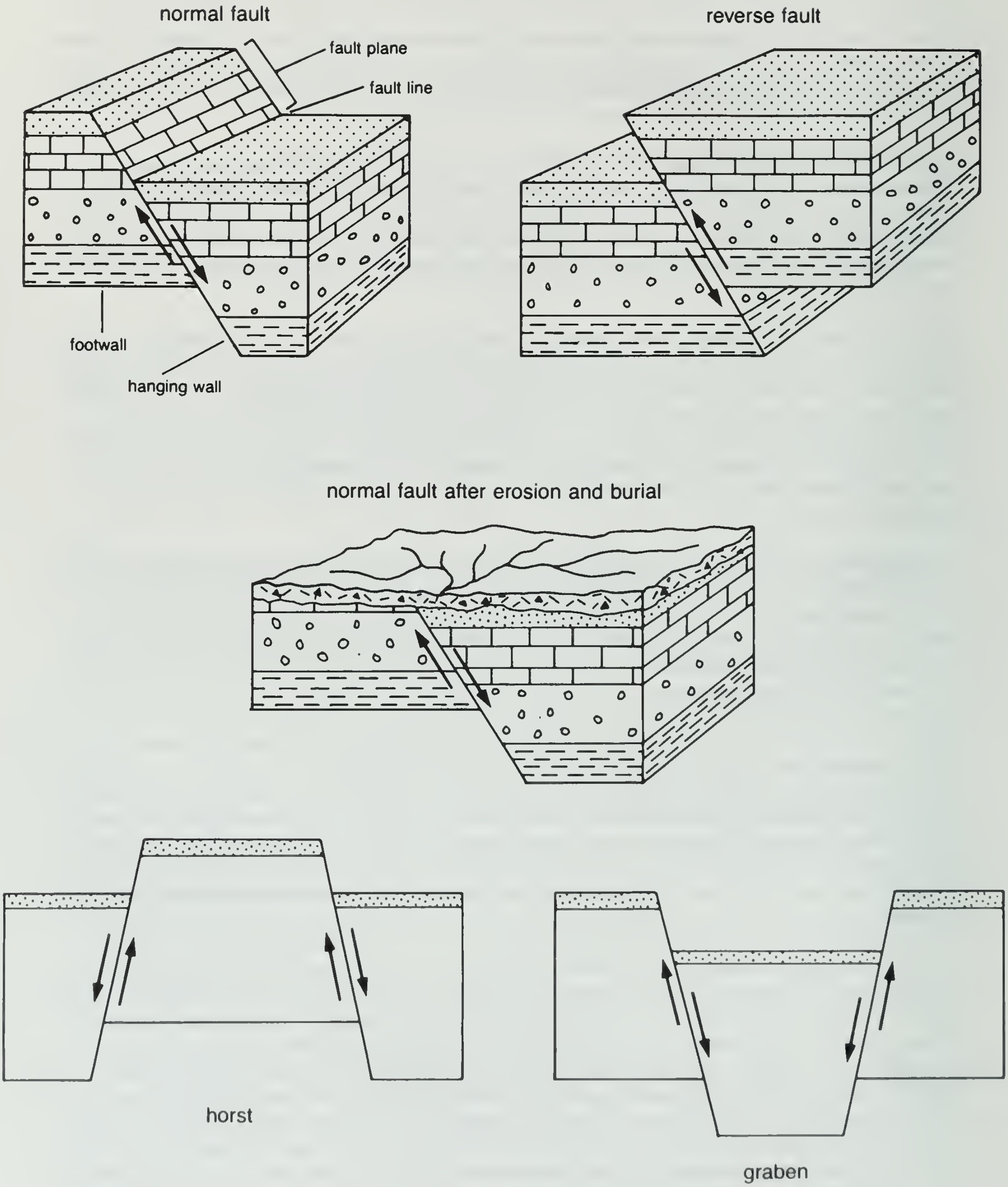


Figure 14 Diagrammatic illustrations of fault types that may be present in the field trip area.

movement of as much as 3,500 feet. The compressive forces that caused this thrusting were probably also responsible for the northeast-southwest-trending fractures along which the block faulting took place.

Recurrent faulting has occurred throughout the region since Permian time, although these later movements may be unrelated to the earlier period of faulting. Cretaceous and Tertiary strata in extreme southern Illinois and in Kentucky are also cut by faults, and earthquakes within recorded history suggest that movements are still taking place. The most recent major earthquakes occurred in southeastern Missouri along the New Madrid Fault in the winter of 1811-1812. Smaller earthquakes have occurred up to the present in several places.

0.0	7.9+	Leave Stop 3 and CONTINUE AHEAD (west). You are traveling along the watershed divide between Peters Creek/Ohio River to the left (south) and Rock Creek/Saline River/Ohio River to the right (north).
1.55+	9.5+	T-road from the left (880N, 1000E). TURN LEFT (south).
0.4	9.9+	CAUTION: cross narrow culvert and ford.
0.25	10.15+	CAUTION: cross narrow concrete ford.
0.2+	10.4+	Y-intersection (795N, 1030E). BEAR LEFT (south).
0.3	10.7+	To the left is another illegal dump. Notice how material has been flushed downstream!
0.9	11.6+	Enter macadam road.
0.15	11.75+	CAUTION: heavy truck traffic enters from the left at Y-intersection (680N, 1080E) at quarry entrance of the Hastie Trucking and Mining Company.
0.95+	12.75+	STOP: 1-way at the T-intersection with SR 146 (585N, 1075E).
2.05+	14.85+	Prepare to stop ahead.
0.15	15.0+	PARK on the road shoulder as far off the pavement as you safely can. CAUTION: FAST TRAFFIC. DO NOT WALK on the pavement! Be careful of where you are stand and what you stand on.

STOP 4 We'll view and study Peters Creek Fault Zone and Chesterian Series (upper Mississippian) strata (N/2 NW NW SE Sec.7, T12S, R9E, 3rd P.M., Hardin County; Rosiclare 7.5-Minute Quadrangle [37088D3]).

The formations exposed in the roadcut are the Chesterian Series Bethel Sandstone and the Downeys Bluff Limestone (fig.11). The Bethel is a light gray, fine- to medium-grained sandstone that weathers tan. The Downeys Bluff consists principally of gray to brownish gray, fossiliferous, oölitic limestone, which can be seen near the east end of the roadcut, south of the highway.

The exposure occurs in a narrow, downfaulted block (graben) within the Peters Creek Fault Zone and affords an excellent opportunity to observe the effects of faulting close-up. The fault that bounds the graben (fig. 14) on the northwest passes along the east edge of Peters Creek. The fault that bounds it on the southeast passes about 300 yards east of the roadcut, beyond

the dip in the highway. Along these faults in this vicinity, the Bethel and the Downeys Bluff have been faulted against the older Ste. Genevieve and St. Louis Limestones.

Within the graben, a small fault cuts across and passes through the roadcut near the east end. It is a normal fault, downthrown on the northwest side. The Bethel has been faulted against the Downeys Bluff. The steep northwestward tilt of the sandstone is the result of drag (friction) during faulting that bent the beds upward along the fault plane. The fault is not a clean break, but rather it consists of a zone of intensely fractured and crushed rock.

Fine-grained, clayey material, containing angular fragments of sandstone, occurs beneath the sandstone. This material, a fault gouge, was formed by grinding action along the fault. In some places it has been shoved up into the sandstone. The gouge is light brownish gray with greenish and reddish patches caused by mixing with shale of the same colors from the top part of the Downeys Bluff.

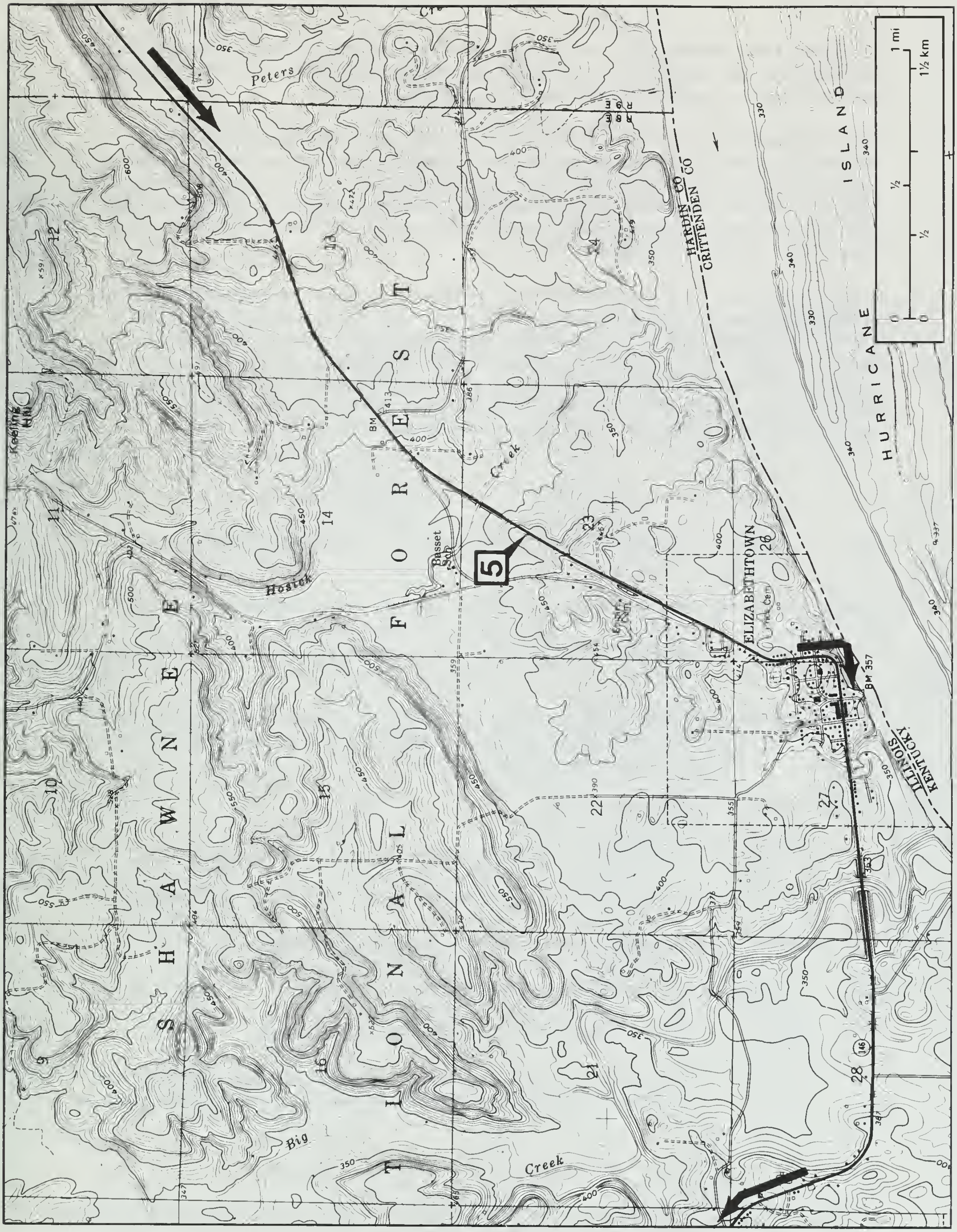
0.0	15.0+	Leave Stop 4 and CONTINUE AHEAD (west).
0.1+	15.15+	Cross Peters Creek.
1.3	16.45+	Roadcut exposes Valmeyeran (middle Mississippian) Ste. Genevieve Limestone.
0.85	17.3+	Entrance to the Hardin County K-12 school is to the right. CONTINUE AHEAD (west).
0.35	17.65+	Cross Hosick Creek.
0.05	17.7+	Prepare to stop ahead.
0.15	17.85+	PARK on the road shoulder as far off the pavement as you safely can. CAUTION: FAST TRAFFIC. DO NOT WALK on the pavement! Be careful of where you stand and what you stand on.

STOP 5 We'll view and study Valmeyeran (middle Mississippian) Ste. Genevieve and St. Louis Limestones in the roadcut (SE SE NE NW Sec. 23, T12S, R8E, Hardin County; Rosiclare 7.5-Minute Quadrangle [37088D3]).

At this exposure, we'll have the opportunity to examine the Ste. Genevieve and the St. Louis Limestones and the contact between these two formations. Note the deeply pitted upper surface of the exposure. Residual red clay, derived from weathering of the limestone, occurs in the solution cavities.

The St. Louis is predominantly a cherty, brownish gray, fine-grained limestone, but it contains some beds of fossiliferous limestone, dolomitic limestone, and oölitic limestone. It ranges from 350 to 400 feet thick in the field trip area. In the upper part, exposed here, the St. Louis is oölitic and contains numerous large chert nodules, which weather brown and have smooth outer boundaries. The limestone exhibits slight fluorspar mineralization.

The overlying Ste. Genevieve Limestone is 140 to 160 feet thick and consists of relatively chert-free limestone of variable character, including medium to light gray, oölitic limestone that is diagnostic of the formation. Interbedded with the oölitic limestone are beds of crystalline, fossiliferous limestone and fine-grained, dense, almost lithographic limestone. Several lenticular, sandy layers, sub-Rosiclare sandstones, occur at various intervals within the formation. The



SHAWNEE NATIONAL FOREST
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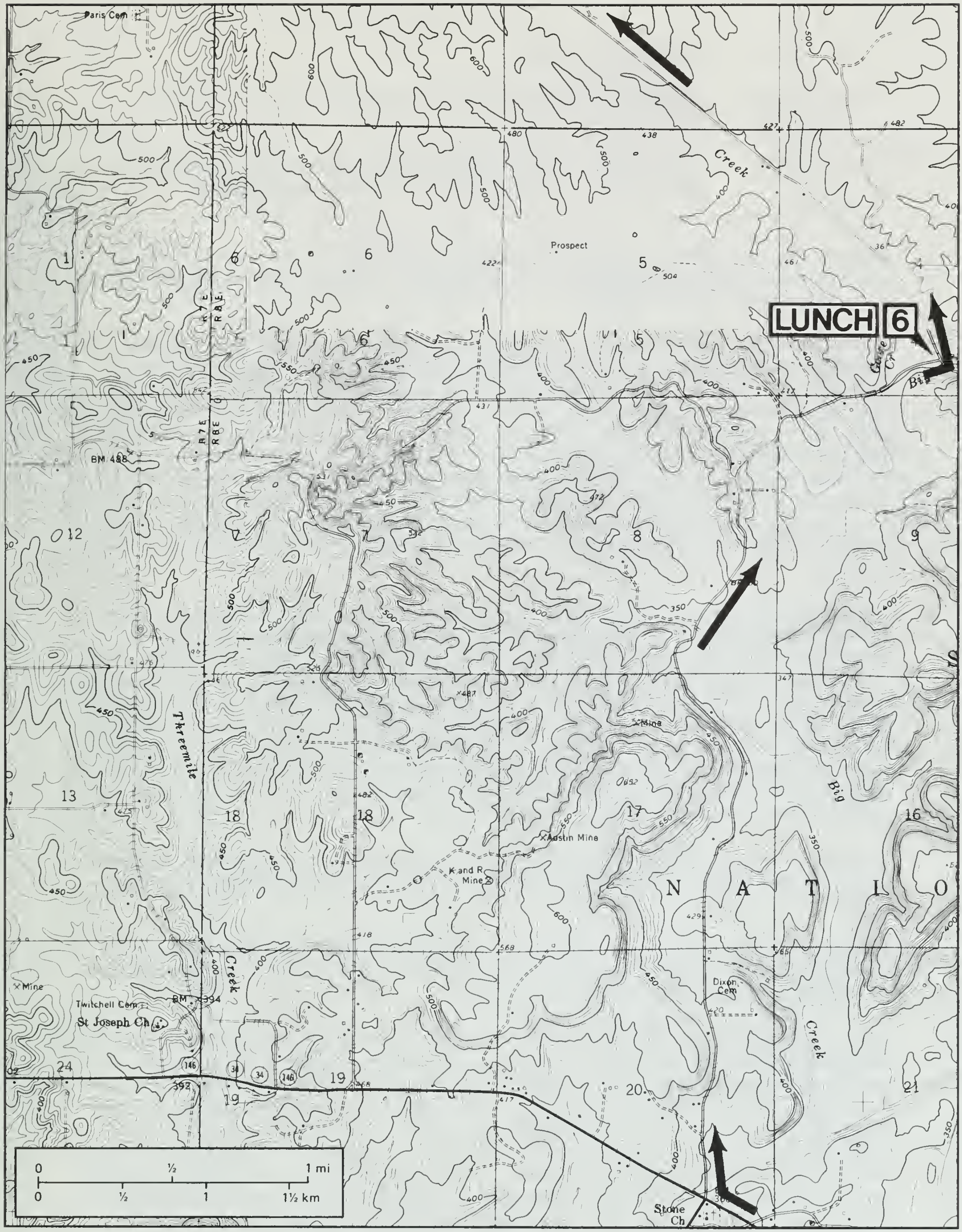
Ste. Genevieve is divided, in ascending order, into four members: the Fredonia Limestone, the Spar Mountain Sandstone, the Karnak Limestone, and the Joppa Limestone. The lowermost Fredonia Member is exposed here above the St. Louis Limestone.

The contact between the St. Louis and the Ste. Genevieve is conformable (nonerosional). Although the contact is gradational, the change from slightly oölitic, fine-grained limestone to extremely oölitic, coarser-grained limestone can be seen here. A small, weathered re-entrant (a slight notch formed in weaker materials) marks the approximate contact at the base of the Fredonia. The Fredonia contains little chert and is markedly crossbedded. The underlying St. Louis is highly cherty and massive.

During Mississippian time, the Midcontinent of North America was a generally low-lying stable platform. Clear, warm, shallow seas entered the region, and the Mississippi Valley region remained almost continually submerged throughout the Mississippian Period (about 360 to 320 million years ago). During the middle part of the period, the seas reached far to the north, and relatively pure limestones, such as the St. Louis and the Ste. Genevieve, were deposited over enormous areas. During the latter part of the period, the seas became more restricted, and the numerous shales and sandstones of the Chesterian Series were deposited.

0.0	17.85	Leave Stop 5 and CONTINUE AHEAD (southwest).
0.5	18.35+	Look left for a view of the Ohio River Valley. The distant hills are in Kentucky.
0.2+	18.55+	The road to the right leads to the U.S. Forest Service district office.
0.05	18.6+	CAUTION: enter Elizabethtown. Look left for a view up the Ohio River Valley.
0.65	19.25+	STOP: 4-way at intersection of Main and First Streets. The historic Rose Hotel is 0.05 mile to the left overlooking the Ohio River. CONTINUE AHEAD straight (west) on SR 146.
0.65+	19.95+	Cross Big Creek.
1.4+	21.35+	Abandoned mine shaft is to the right.
0.35+	21.75	Junction of SR 146 and SR 34. TURN RIGHT (north) on the gravel road.
0.4	22.15	Left roadcut shows Chesterian Menard Limestone.
0.7	22.85	Left roadcut shows Chesterian Clore Formation.
0.7-	23.5+	Menard Limestone is on the left side of the roadway.
0.4+	23.95	Valmeyeran (middle Mississippian) Salem Limestone is exposed in this road cut. The dark gray to black limestone has numerous white corals in it.
0.4+	24.4-	Salem Limestone is exposed in the cut to the right.
0.2+	24.6	Y-intersection with U.S. Forest Service (USFS) road 118. BEAR RIGHT (northeast) toward the Iron Furnace.


LUNCH 6
Paris Cem
Creek
Prospect
BM 488
Threemile
Creek
Big
Creek
Mine
Austin Mine
K and R Mine
N A T I O
Dixon Cem
Twitchell Cem
St Joseph Ch
BM 394
Stone Ch
R 7 E
R 8 E
0 ½ 1 mi
0 ½ 1 1½ km

0.6+	25.2+	Cross Goose Creek.
0.25	25.45+	CAUTION: unguarded T-road intersection on a curve. TURN LEFT (north) on USFS 141.
0.05-	25.5+	TURN RIGHT into the parking area of the Illinois Iron Furnace picnic ground. PARK as close to the car in front of you as you can.

STOP 6 We'll eat LUNCH and visit the Illinois Iron Furnace (NW SW SE Sec. 4, T12S, R8E, 3rd P.M., Hardin County; Rosiclare 7.5-Minute Quadrangle [37088D3]). Please DO NOT CLIMB on the iron furnace or other structures.

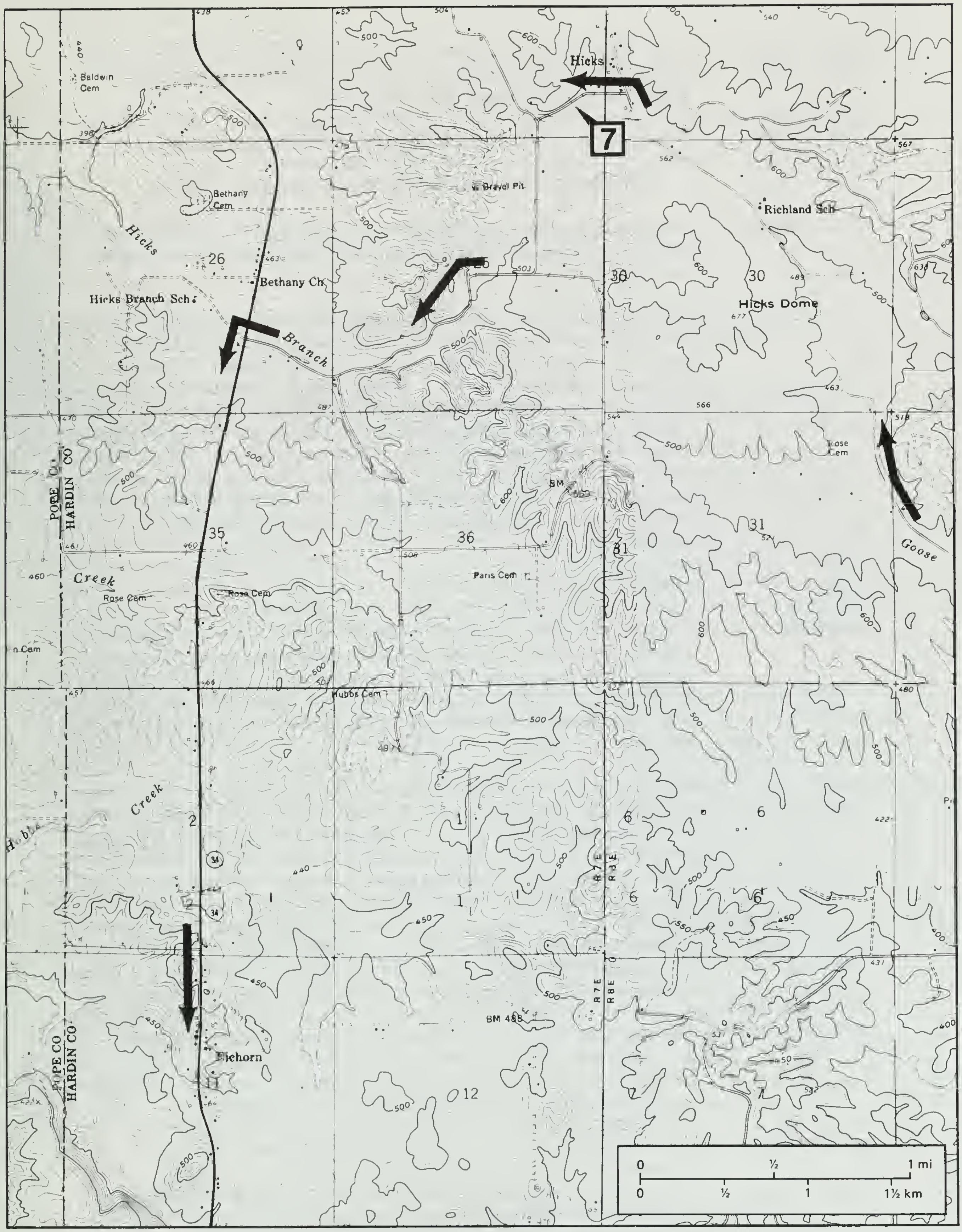
Hardin County, at one time known for its iron deposits, is the only county in Illinois where smelting furnaces for reducing local iron ore deposits were ever built. Illinois Furnace, one of only two such furnaces in Illinois, was constructed in about 1837. The hearth and inner walls originally were built of Mississippian sandstone with a lining of firebrick from Ohio; the outer walls were constructed from blocks of dark gray Salem Limestone. The furnace may not have initially functioned properly, because it was rebuilt and enlarged in 1856 to a height of 32 feet. The present structure was rebuilt in the mid-1960s by the U.S. Government under the Job Corps Program in an attempt to reproduce the furnace as it appeared in the mid-1800s. The present furnace was constructed from plans that were largely drawn from those used to rebuild an Ohio furnace. The furnace certainly is representative of the furnaces built and used during this time.

The furnace used an ore, called limonite, that contained more than 80% oxides of iron. This material ranged from gravel-sized to much larger. The ore bodies occurred in pockets of comparatively small size in the upper surfaces of the Mississippian limestones, particularly the St. Louis and Ste. Genevieve. The ore was associated with accumulations of residual clay and, in some cases, with abundant chert. Several pits in these pocket ores operated at one time or another in this vicinity. Early ISGS reports stated that the ore was first burned on log-heaps to expel its water content. The roasted ore was then ready for charging the furnace. Two hundred bushels of hardwood charcoal were needed to produce 1 ton of pig iron. Nine tons of pig iron were reportedly produced every 24 hours. The furnace operated from 6 to 9 months each year, depending on the ready availability of iron ore.

The second furnace, Martha Furnace, was smaller and was located about 2.5 miles northeast of here. Martha Furnace was operated from 1848 to 1857 and rapidly deteriorated after its closing.

The early ISGS reports state that the furnaces were closed down in 1861 at the start of the Civil War. However, pig iron reportedly was produced at Illinois Furnace for the Naval Shipyard 50 miles to the southwest at Mound City, Illinois.

As we look around the rustic setting here, it is hard to imagine all of the activity that took place near this operation. Several workers at the furnace charged the furnace with charcoal and iron ore and then kept it stoked. Others worked the runs from the furnace to the "pig house" where the molds for pig iron had been fashioned out of the ground. Sluice gates were used to divert the molten iron from one full mold to a neighboring empty one. In addition, men dug the ore and loaded it into horse- or mule-drawn wagons that were brought here. There was also quite an industry involved in producing the charcoal needed to fire the furnace. Not only did men fell hardwood timber with axes and handdrawn saws, they also brought the wood to the charcoal kiln site, stacked the wood for burning, and then transported the finished charcoal to the iron furnace. Once the "pigs" had cooled, they were taken to Rosiclare for transport on the river.



Hicks
7
Baldwin Cem
Bethany Cem
Gravel Pit
Richland Sch
Hicks
26
Bethany Ch
Hicks Branch Sch
Branch
25
30
Hicks Dome
POPE CO
HARDIN CO
35
36
31
Goose
Creek
Rose Cem
Paris Cem
Hubbs Cem
Creek
2
1
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R7E
R8E
BM 488
Elchorn
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12
7
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0.05-	25.55-	Leave Stop 6. TURN RIGHT (northwest) at the northwest end of the parking lot onto the gravel road (USFS 141).
0.45	26.0	T-road intersects from right. CONTINUE AHEAD (northwest).
1.3+	27.3+	T-road intersects from right. CONTINUE AHEAD (northwest).
0.1+	27.45	The lane to the right goes north for about 0.25 mile to an abandoned gravel pit that was developed in the Valmeyeran (middle Mississippian) Fort Payne Formation. The Fort Payne Formation is a thick unit (270 to 615 feet thick) that ordinarily consists of dark gray to black, calcareous siltstone or silty limestone. In the hilly belt surrounding Hicks Dome, however, the formation has been completely leached by weathering. The exposures consist mainly of noncalcareous chert that occurs in regular layers up to 1 foot thick and separated by thin layers of clay. The interlayering is excellently displayed in this abandoned quarry. The chert and clay are iron-stained, but some beds are pure white. Most of the chert was probably quarried for roadstone. Some of the chert is porous and fairly soft, and it is commonly referred to as "cotton rock." Some of this material was sold as chicken litter. CONTINUE AHEAD (northwest).
0.25+	27.7+	Y-intersection (765N, 300E). BEAR RIGHT (north). When cleaned off, roadcuts here show the Upper Devonian New Albany shale. The New Albany Shale is also extensively exposed along the creek to the left. The shale is cut by an igneous peridotite dike that crosses the east-flowing tributary to Goose Creek about 800 yards upstream to the west from here. Dikes in the Fluorspar District range in width from a few inches to more than 100 feet. They generally are oriented with their long dimension toward the northwest. A dike is a tabular body of igneous rock that has intruded across the bedding or layering of the host rock. As mentioned earlier, the dikes were squeezed upwards into northwest-trending tension fractures when the area was domed by a large, deep-seated body of magma. The dikes generally consist of dark gray or greenish gray, porphyritic mica-peridotite, composed principally of olivine, pyroxene, and brown mica. The olivine is almost always altered to serpentine, and there has been intense alteration of the rock to carbonate and chlorite as well. The dike mentioned above is about 2 to 3 feet thick. A second dike, a few inches thick, about 50 feet to the northeast of the first one, occurs within a 10-foot zone of intensely brecciated New Albany Shale. The dike rock is badly decomposed and iron-stained by weathering.
0.45+	28.15+	Cross the concrete ford. The hill ahead is Hicks Dome.
0.45	28.6+	The site of an abandoned fluorspar test pit is to the left. CONTINUE AHEAD (north). Nearly 500 yards to the northeast is another mica-peridotite dike; this one is oriented northeast to southwest.

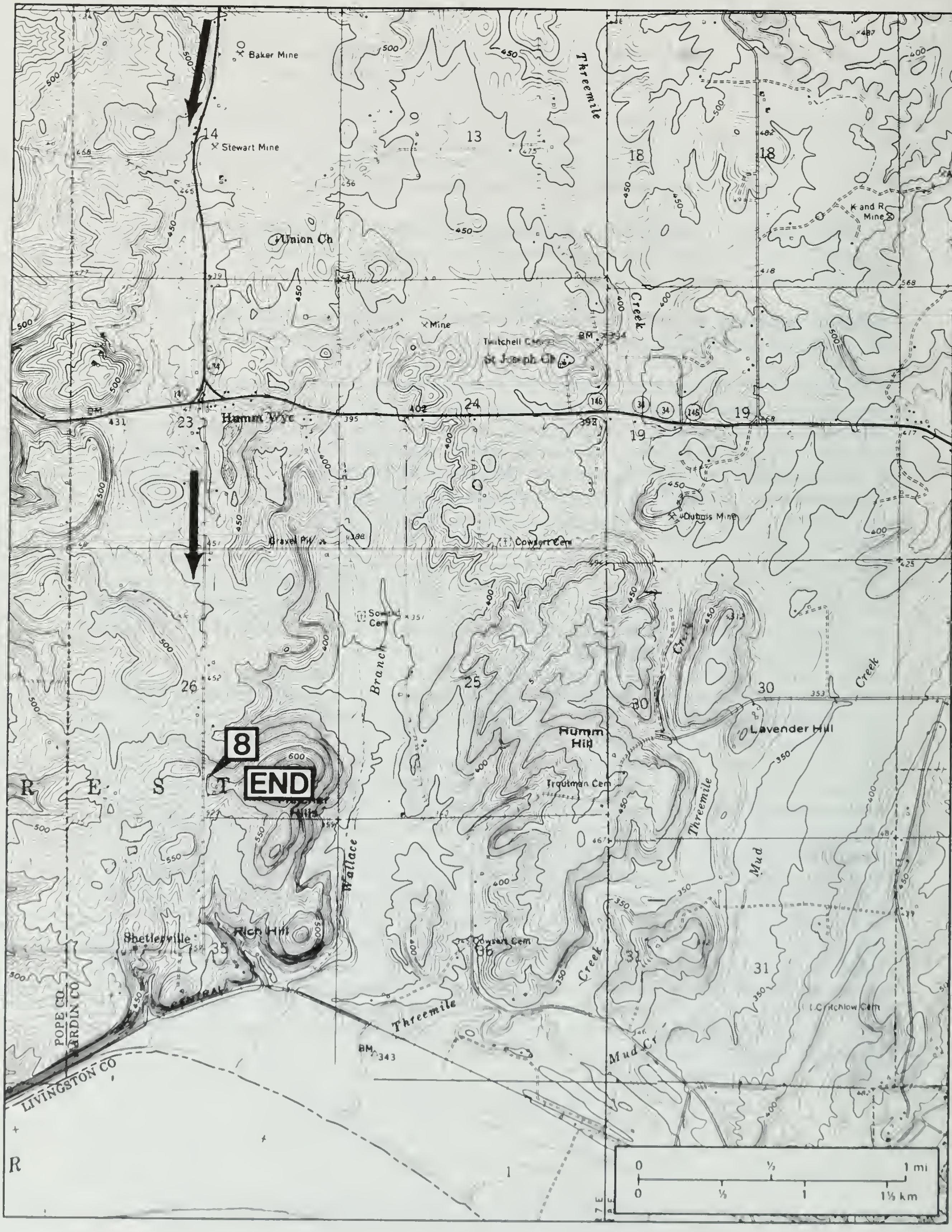
0.25+	28.9	Abandoned lane on the left formerly provided access to the top of Hicks Dome.
0.45+	29.35+	T-intersection from right (900N, 225E). CONTINUE AHEAD (northwest).
0.3	29.7	T-intersection (915N, 205E) at the community of Hicks. TURN LEFT (west) around the northern edge of Hicks Dome.
0.2	29.9	PARK along the road shoulder as far off the road as you safely can. CAUTION: watch for traffic.

STOP 7 We'll view and discuss Hicks Dome from the north-northwest (SW NE SE SE Sec. 24, T11S, R7E, 3rd P.M., Hardin County; Herod 7.5-Minute Quadrangle [37088E4]).

Hicks Dome is an elliptical uplift of about 100 square miles, with the long axis oriented toward the northwest. Maximum uplift at its apex is estimated to be about 4,000 feet. Erosion has truncated the structure and exposed limestone and chert of Middle and Early Devonian age at the center. Younger Devonian, Mississippian, and Pennsylvanian formations are exposed around the flanks. The beds dip away from the apex in all directions, the steepest dips occurring on the northwest. The New Albany Shale occupies a depression between the Devonian limestone and chert of the central high area and the resistant, cherty limestone of the Fort Payne Formation, which forms a prominent encircling ridge. The circular outcrop pattern of the younger Mississippian formations is interrupted on the southeast by a large southwest-trending fault that is downthrown to the southeast. Two other major southwest-trending faults cut across the structure near the apex. On three sides, the dome is rimmed by a discontinuous system of curved faults. At least five igneous dikes and four patches of brecciated rock, up to 200 feet in diameter, occur within the central area (fig. 5).

Geologists have puzzled over the origin of Hick's Dome for a long time. Most believe that the structure is related to the period of faulting and igneous activity that took place in Permian time. The breccias, consisting of masses of broken rock, suggest that some sort of explosive action was involved. The Hicks Dome Breccia (found in this vicinity), the Hamp Breccia (just to the northwest), and the Rose Mine Breccia (to the southeast) consist of angular fragments of sedimentary rocks in a matrix of finely ground sedimentary rock. Other breccias in the Fluorspar District, such as the Sparks Hill Breccia 6 miles to the northeast, and the Grants Intrusive 2 miles to the south, also contain fragments of igneous rocks and minerals (granite, quartz, pyroxene, amphibole, apatite, mica, and feldspar) that strongly indicate a deep-seated origin. Recent drilling of the Hamp Breccia showed sedimentary strata that were intensely brecciated to a depth of at least 3,000 feet in rocks of Ordovician age. The form of the breccia in the subsurface is not definitely known, but the oval shapes in outcrop and the drilling data indicate that they may be pipe-like features. The doming and brecciation of the strata may have been caused by the relatively sudden release of gases that had accumulated at the top of a large body of magma mentioned earlier. Another theory is that the explosion was caused by steam generated from water contained in the sedimentary rocks, which were heated as a result of the intrusion of the igneous dikes.

0.0	29.9	Leave Stop 7; CONTINUE AHEAD (southwest).
0.15	30.05	Y-intersection (905N, 175E). BEAR LEFT (south).
0.55+	30.6+	T-intersection (850N, 175E). TURN RIGHT (west) on USFS 140.
0.1	30.7+	CAUTION: cross concrete ford.


Baker Mine
Stewart Mine
Union Ch
Threemile
Creek
K and R Mine
Mine
Twitchell Cem
St Joseph Ch
Humm Wye
Gravel Pit
Cowsert Cem
Dubois Mine
Sowerd Cem
Branch
Wallace
Humm Hill
Troutman Cem
Lavender Hill
Mud
8
END
Rich Hill
Shetlerville
Cowsert Cem
Critchlow Cem
Mud Cr
BM 343
POPE CO
HARDIN CO
LIVINGSTON CO
CENTRAL
0
½
1 mi
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½
1
1½ km

0.15+	30.9	Look left for a view of the southern end of Hicks Dome.
0.1+	31.0+	Look left. The view on the other side of the creek is the Devonian-Mississippian New Albany and overlying Valmeyeran Fort Payne rocks tilted 20° to the west-southwest.
0.35+	31.4+	Cross concrete ford. Mississippian Fort Payne strata are exposed on the south side of Hicks Branch with about a 12° west-southwest dip.
0.05+	31.5	Look right for a view of Valmeyeran Ullin Limestone in the creek with a 10° west-southwest dip.
0.05+	31.55+	T-intersection from left (820N, 100E). CONTINUE AHEAD (west) and cross a fault in about 400 feet.
0.15+	31.7+	LOOK RIGHT for a view of Mississippian (Valmeyeran) Salem Limestone dipping about 20° west.
0.2	31.9+	STOP: 2-way at intersection with SR 34. CAUTION: fast traffic. TURN LEFT (south) on SR 34.
2.45+	34.4	CAUTION: you are entering the hamlet of Eichorn. Six abandoned mines are located within a 0.5-mile radius; the closest is about 100 feet west of the highway.
1.0+	35.4+	In the next 0.5 mile, eight abandoned mine sites lie to the left (east) within 500 feet of the highway; some are extremely hard to see.
0.45+	35.9	For the next 0.85+ mile (to about 200 feet south of SR 146), there are 14 abandoned mine sites within 0.55 mile of the west side of SR 34.
0.85	36.75	STOP: 2-way at junction of SR 34 and SR 146. CONTINUE AHEAD (south) on macadam.
1.4	38.15	PARK as far off the roadway as you safely can. Heavy truck traffic. CAUTION: do not stand on the roadway. Be very careful in crossing the road. Watch out for snakes.

STOP 8 We'll view and collect from the Chesterian (upper Mississippian) Downeys Bluff Limestone (SE NE SE SW Sec. 26, T12S, R7E, 3rd P.M., Hardin County; Shetlerville 7.5-Minute Quadrangle [37088D4]).

The Downeys Bluff, 25 to 40 feet thick, consists of gray and brownish gray, fine- to coarse-grained fossiliferous limestone, locally oölitic, occurring in thin to medium beds, some of which are noticeably crossbedded (Baxter et al. 1967). Light gray shale interbeds are present, as is some pink or gray chert, especially in the upper part. Its basal contact is transitional and marked with an increase in the amount of shale with the underlying Yankeetown Shale. The limestone is inconformably overlain by the Bethel Sandstone.

End of the field trip to Cave-in-Rock. Have a safe journey home.

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MISSISSIPPIAN DEPOSITION

(The following quotation is from Report of Investigations 216: Classification of Genevievian and Chesterian...Rocks of Illinois [1965] by D. H. Swann, pp. 11-16. One figure and short sections of the text are omitted.)

During the Mississippian Period, the Illinois Basin was a slowly subsiding region with a vague north-south structural axis. It was flanked by structurally neutral regions to the east and west, corresponding to the present Cincinnati and Ozark Arches. These neighboring elements contributed insignificant amounts of sediment to the basin. Instead, the basin was filled by locally precipitated carbonate and by mud and sand eroded from highland areas far to the northeast in the eastern part of the Canadian Shield and perhaps the northeastward extension of the Appalachians. This sediment was brought to the Illinois region by a major river system, which it will be convenient to call the Michigan River (fig. 4) because it crossed the present state of Michigan from north to south or northeast to southwest....

The Michigan River delivered much sediment to the Illinois region during early Mississippian time. However, an advance of the sea midway in the Mississippian Period prevented sand and mud from reaching the area during deposition of the St. Louis Limestone. Genevievian time began with the lowering of sea level and the alternating deposition of shallow-water carbonate and clastic units in a pattern that persisted throughout the rest of the Mississippian. About a fourth of the fill of the basin during the late Mississippian was carbonate, another fourth was sand, and the remainder was mud carried down by the Michigan River.

Thickness, facies, and crossbedding...indicate the existence of a regional slope to the southwest, perpendicular to the prevailing north 65° west trend of the shorelines. The Illinois Basin, although developing structurally during this time, was not an embayment of the interior sea. Indeed, the mouth of the Michigan River generally extended out into the sea as a bird-foot delta, and the shoreline across the basin area may have been convex more often than concave.

....The shoreline was not static. Its position oscillated through a range of perhaps 600 to 1000 or more miles. At times it was so far south that land conditions existed throughout the present area of the Illinois Basin. At other times it was so far north that there is no suggestion of near-shore environment in the sediments still preserved. This migration of the shoreline and of the accompanying sedimentation belts determined the composition and position of Genevievian and Chesterian rock bodies.

Lateral shifts in the course of the Michigan River also influenced the placement of the rock bodies. At times the river brought its load of sediment to the eastern edge of the basin, at times to the center, and at times to the western edge. This lateral shifting occurred within a range of about 200 miles. The Cincinnati and Ozark areas did not themselves provide sediments, but, rather, the Michigan River tended to avoid those relatively positive areas in favor of the down-warped basin axis.

Sedimentation belts during this time were not symmetrical with respect to the mouth of the Michigan River. They were distorted by the position of the river relative to the Ozark and Cincinnati shoal areas, but of greater importance was sea current or drift to the northwest. This carried off most of the mud contributed by the river, narrowing the shale belt east of the river mouth and broadening it west

of the mouth. Facies and isopach maps of individual units show several times as much shale west of the locus of sand deposition as east of it. The facies maps of the entire Chesterian...show maximum sandstone deposition in a northeast-southwest belt that bisects the basin. The total thickness of limestone is greatest along the southern border of the basin and is relatively constant along that entire border. The proportion of limestone, however, is much higher at the eastern end than along the rest of the southern border, because little mud was carried southeastward against the prevailing sea current. Instead, the mud was carried to the northwest and the highest proportion of shale is found in the northwestern part of the basin.

Genevievian and Chesterian seas generally extended from the Illinois Basin eastward across the Cincinnati Shoal area and the Appalachian Basin. Little terrigeneous sediment reached the Cincinnati Shoal area from either the west or the east, and the section consists of thin limestone units representing all or most of the major cycles. The proportion of inorganically precipitated limestone is relatively high and the waters over the shoal area were commonly hypersaline... Erosion of the shoal area at times is indicated by the presence of conodonts eroded from the St. Louis Limestone and redeposited in the lower part of the Gasper Limestone at the southeast corner of the Illinois Basin...

The shoal area included regions somewhat east of the present Cincinnati axis and extended from Ohio, and probably southeastern Indiana, through central and east-central Kentucky and Tennessee into Alabama....

Toward the west, the seaway was commonly continuous between the Illinois Basin and central Iowa, although only the record of Genevievian and earliest Chesterian is still preserved. The seas generally extended from the Illinois and Black Warrior regions into the Arkansas Valley region, and the presence of Chesterian outliers high in the Ozarks indicates that at times the Ozark area was covered. Although the sea was continuous into the Ouachita region, detailed correlation of the Illinois sediments with the geosynclinal deposits of this area is difficult.

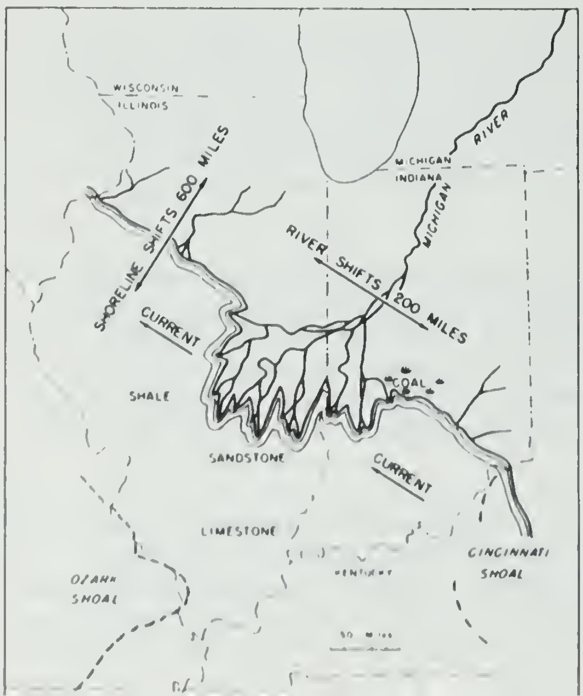
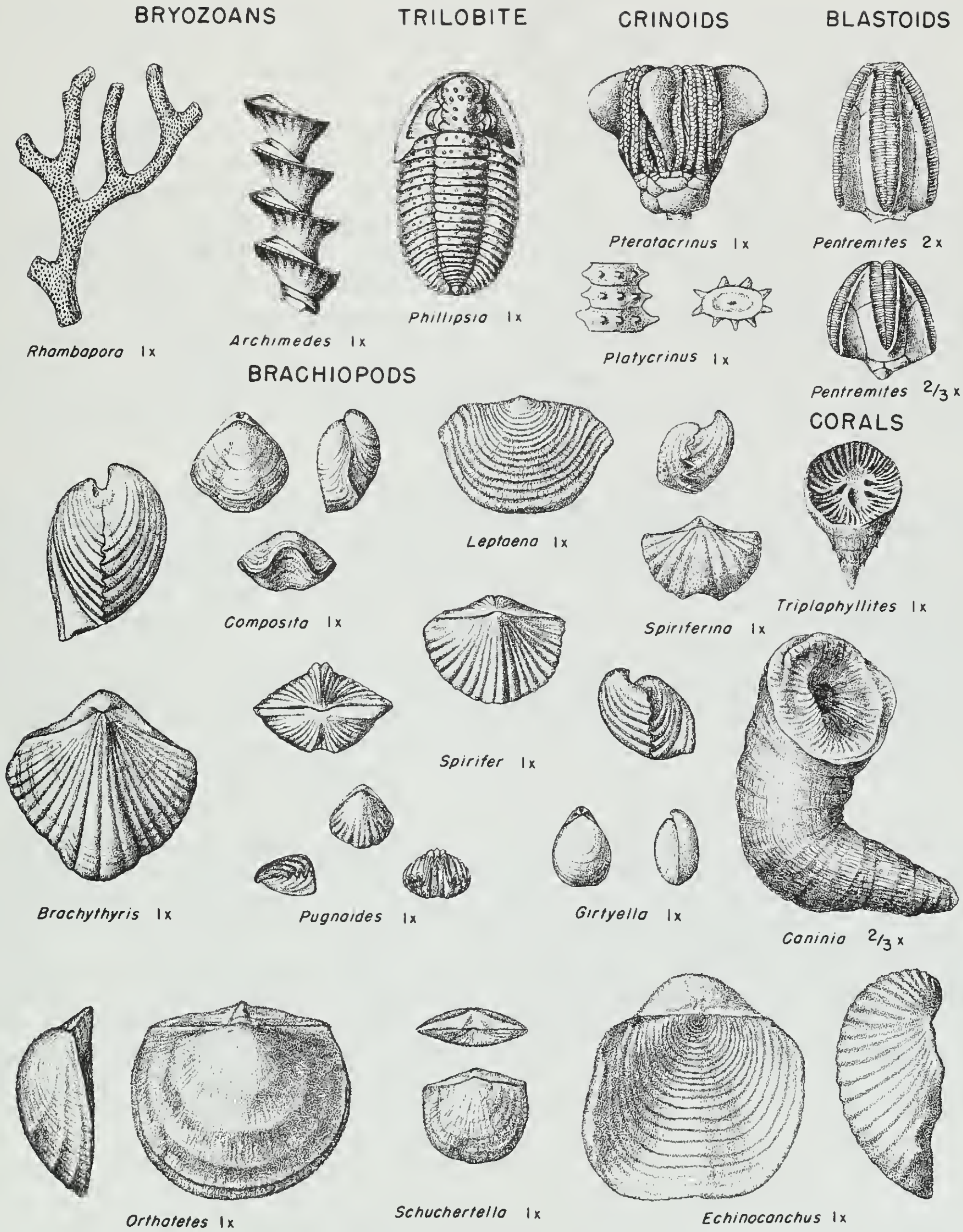


Figure 4: Paleogeography at an intermediate stage during Chesterian sedimentation.


BRYOZOANS
TRILOBITE
CRINOIDS
BLASTOIDS
Rhambopora 1x
Archimedes 1x
Phillipsia 1x
Pteratacrinus 1x
Platycrinus 1x
Pentremites 2x
Pentremites 2/3 x
BRACHIOPODS
CORALS
Composita 1x
Leptaena 1x
Spiriferina 1x
Triplophyllites 1x
Spirifer 1x
Brachythyris 1x
Pugnaides 1x
Girtyella 1x
Caninia 2/3 x
Orthatetes 1x
Schuchertella 1x
Echinocanchus 1x

THE TYPICAL MISSISSIPPIAN CHESTERIAN SERIES IN SOUTHWESTERN ILLINOIS
REPRESENTED BY
A COMPOSITE COLUMN AND AN ELECTRIC LOG

The composite column on the following page (RI 216, Pl 1) is a diagram drawn to represent certain rocks layers as they appear in a part of southwestern Illinois. The electric log (e-log) is a record made from instrument observations and recordings of rock layers in the bore of an oil-test well. A geologist made the column, using symbols to briefly express the significant rock unit qualities he could observe. In contrast, the e-log was made by an electrical sensing device lowered and raised in the test well to measure only two specific qualities of the rock layers: resistivity and spontaneous-potential. Together, the correlated column and e-log show in a concise way what the isolated outcrops in the area cannot, i.e., what thicknesses, variations in lithology, and mutual relations the sub-divisions of the Chesterian Series have across the country. In addition, the correlated e-log is a key that may be used to interpret other e-logs in this part of the Illinois Basin.

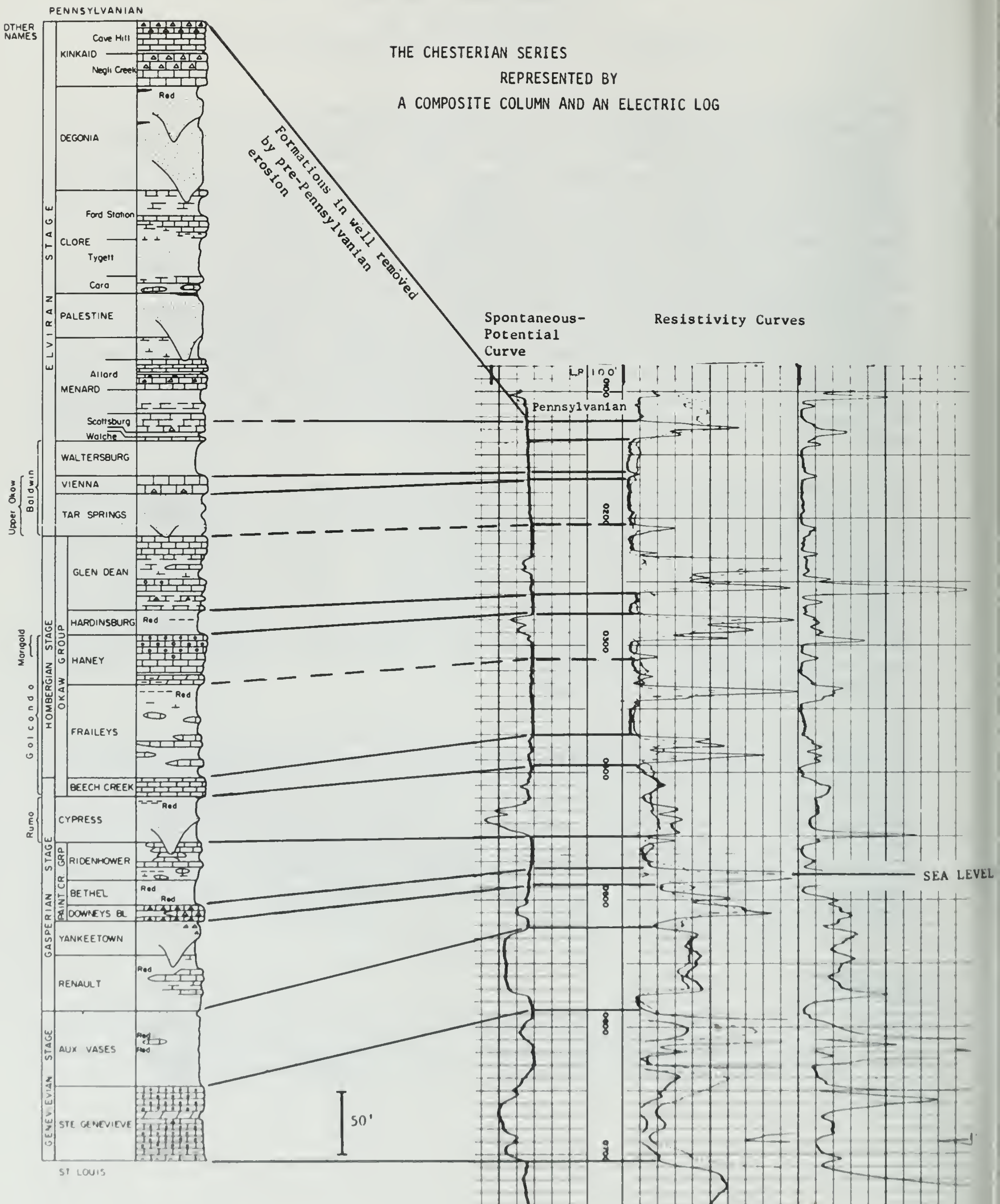
Cross-sections consisting of several corrlelated e-logs reproduced at the same scale are used to demonstrate that: (1) thicker layers of sandstone or shale or limestone--a particular rock unit--are delineated as characteristic shapes by the pair of S-P and resistivity curves, (2) the rock units vary in thickness and composition from one place to another, but many points of similarity persist (the unique curves of some units persist for several hundred miles), and (3) the seemingly abstract curves of the e-log create a pciture in many ways as readable as other illustrations of rock columns.

Because Illinois has been a major oil producer for many years, tens of thousands of e-logs have been made of wells drilled throughout the state. They are the principal tool of the geologists who map deep subsurface geological units (rock layers) and structures, such as anticlines, synclines, monoclinal folds, domes, etc. Because of their value, e-logs and other types of well logs are filed as permanent records at the Illinois State Geological Survey, where they may be examined. NOTE: copies of e-logs may be purchased from companies that reproduce them.

REFERENCE

Swann, D.H., 1963, Classification of Genevievian and Chesterian (Late Mississippian) rocks of Illinois: Illinois State Geological Survey Report of Investigations 216, 91 p.

THE CHESTERIAN SERIES
REPRESENTED BY
A COMPOSITE COLUMN AND AN ELECTRIC LOG



DEPOSITIONAL HISTORY OF THE PENNSYLVANIAN ROCKS IN ILLINOIS

At the close of the Mississippian Period, about 310 million years ago, the sea withdrew from the Midcontinent region. A long interval of erosion that took place early in Pennsylvanian time removed hundreds of feet of the pre-Pennsylvanian strata, completely stripping them away and cutting into older rocks over large areas of the Midwest. Ancient river systems cut deep channels into the bedrock surface. Later, but still during early Pennsylvanian (Morrowan) time, the sea level started to rise; the corresponding rise in the base level of deposition interrupted the erosion and led to filling the valleys in the erosion surface with fluvial, brackish, and marine sands and muds.

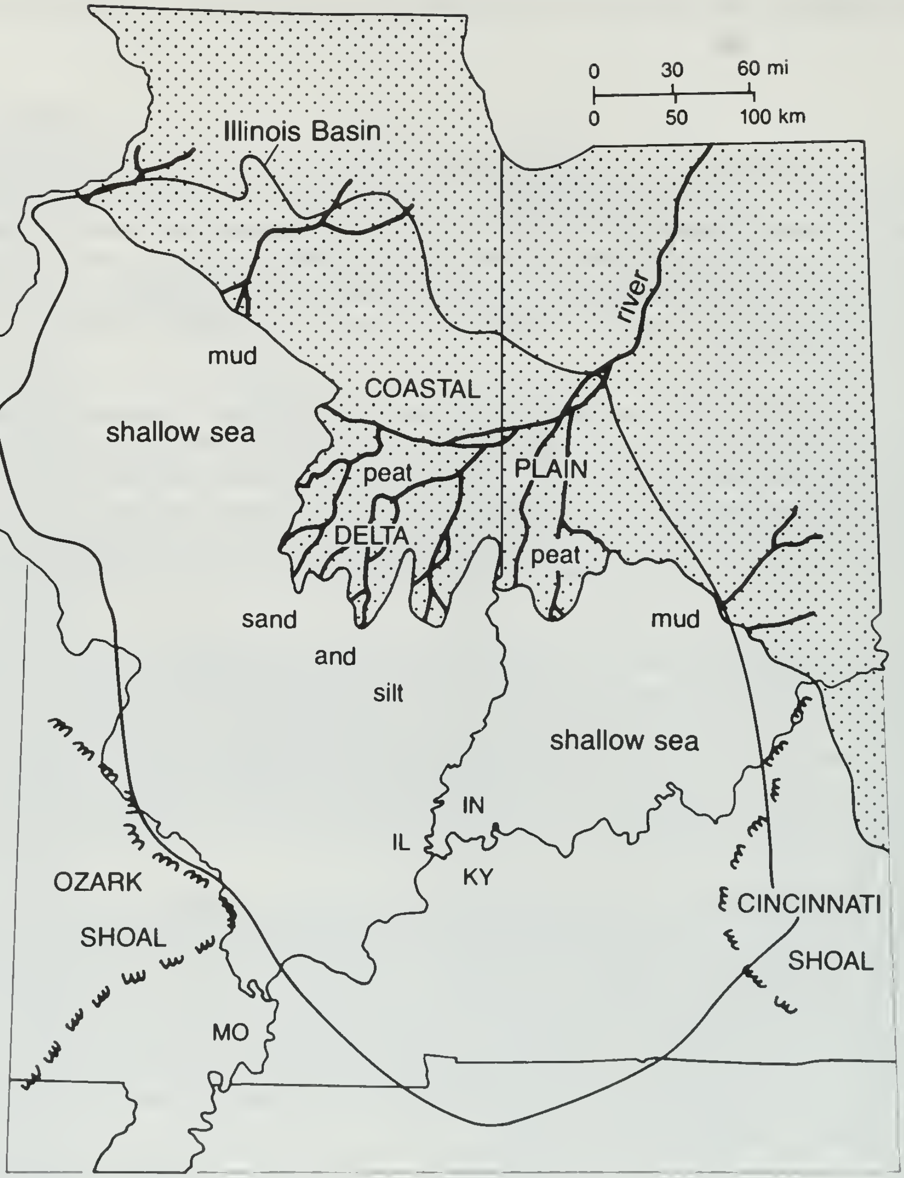
Depositional conditions in the Illinois Basin during the Pennsylvanian Period were somewhat similar to those of the preceding Chesterian (late Mississippian) time. A river system flowed southwestward across a swampy lowland, carrying mud and sand from highlands to the northeast. This river system formed thin but widespread deltas that coalesced into a vast coastal plain or lowland that prograded (built out) into the shallow sea that covered much of present-day Illinois (see paleogeographic map, next page). As the lowland stood only a few feet above sea level, slight changes in relative sea level caused great shifts in the position of the shoreline.

During most of Pennsylvanian time, the Illinois Basin gradually subsided; a maximum of about 3000 feet of Pennsylvanian sediments are preserved in the basin. The locations of the delta systems and the shoreline of the resulting coastal plain shifted, probably because of worldwide sea level changes, coupled with variation in the amounts of sediments provided by the river system and local changes in basin subsidence rates. These frequent shifts in the coastline position caused the depositional conditions at any one locality in the basin to alternate frequently between marine and nonmarine, producing a variety of lithologies in the Pennsylvanian rocks (see lithology distribution chart).

Conditions at various places on the shallow sea floor favored the deposition of sand, lime mud, or mud. Sand was deposited near the mouths of distributary channels, where it was reworked by waves and spread out as thin sheets near the shore. Mud was deposited in quiet-water areas — in delta bays between distributaries, in lagoons behind barrier bars, and in deeper water beyond the nearshore zone of sand deposition. Limestone was formed from the accumulation of limy parts of plants and animals laid down in areas where only minor amounts of sand and mud were being deposited. The areas of sand, mud, and limy mud deposition continually changed as the position of the shoreline changed and as the delta distributaries extended seaward or shifted their positions laterally along the shore.

Nonmarine sand, mud, and lime mud were deposited on the coastal plain bordering the sea. The nonmarine sand was deposited in delta distributary channels, in river channels, and on the broad floodplains of the rivers. Some sand bodies 100 or more feet thick were deposited in channels that cut through the underlying rock units. Mud was deposited mainly on floodplains. Some mud and freshwater lime mud were deposited locally in fresh-water lakes and swamps.

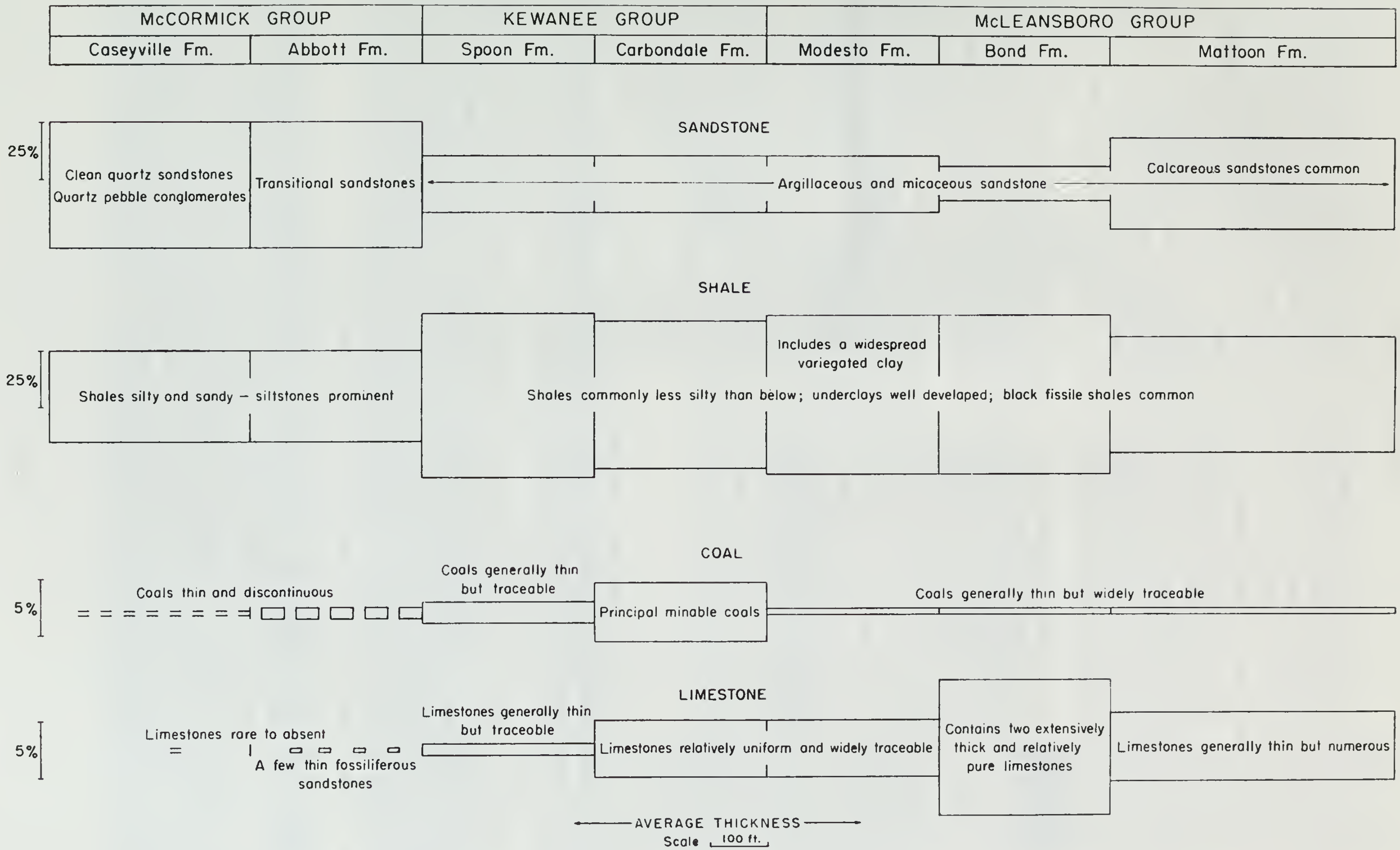
Beneath the quiet water of extensive swamps that prevailed for long intervals on the emergent coastal lowland, peat was formed by accumulation of plant material. Lush forest vegetation covered the region; it thrived in the warm, moist Pennsylvanian-age climate. Although the origin of the underclays beneath the coal is not precisely known, most evidence indicates that they were deposited in the swamps as slackwater mud before the accumulation of much plant debris. The clay underwent modification to become the soil upon which the lush vegetation grew in the swamps. Underclay frequently contains plant roots and rootlets that appear to be in their original places. The vast swamps were the culmination of nonmarine deposition. Resubmergence of the borderlands by the sea interrupted nonmarine deposition, and marine sediments were laid down over the peat.



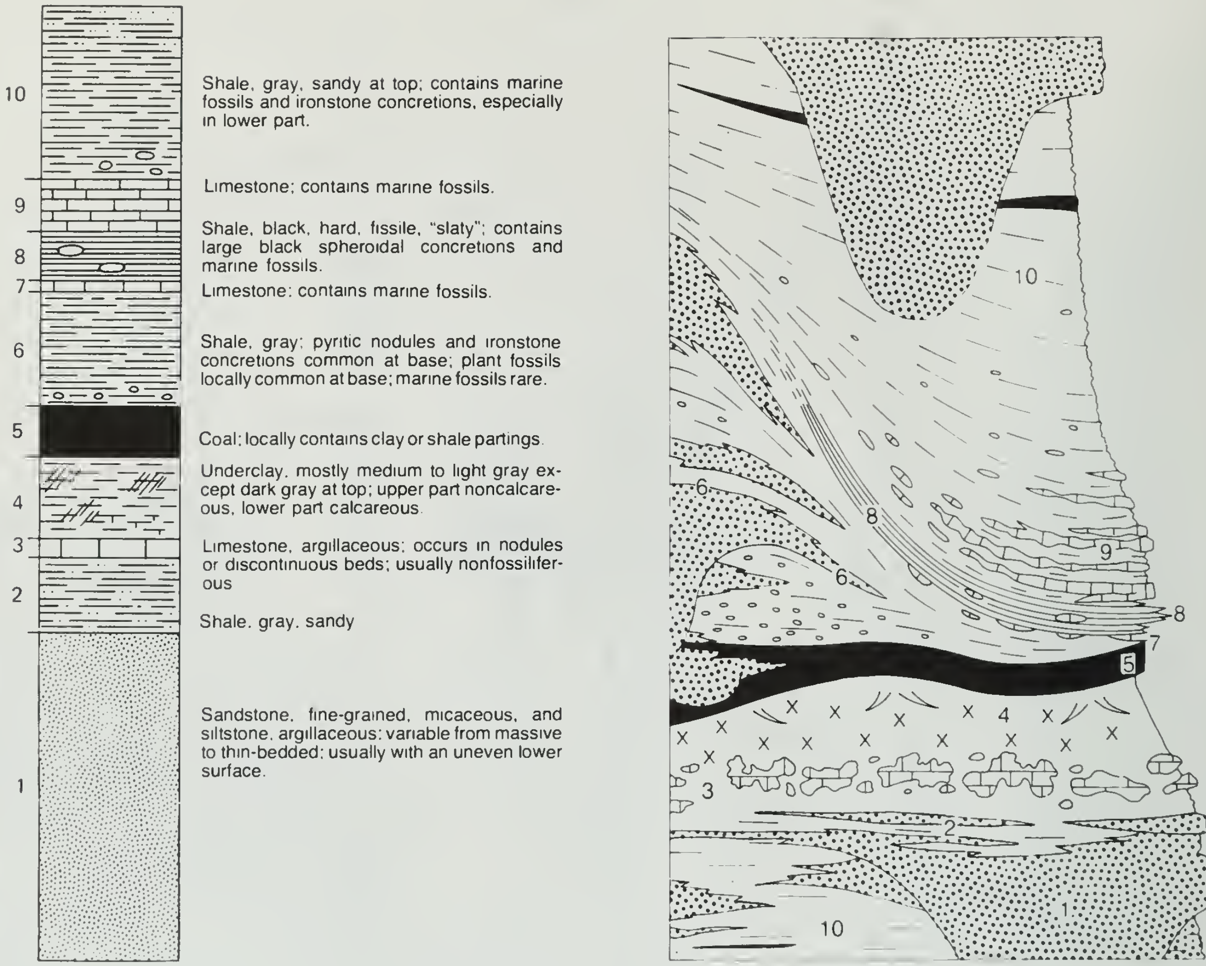
Paleogeography of Illinois-Indiana region during Pennsylvanian time. The diagram shows a Pennsylvanian river delta and the position of the shoreline and the sea at an instant of time during the Pennsylvanian Period.

Pennsylvanian Cyclothems

The Pennsylvanian strata exhibit extraordinary variations in thickness and composition both laterally and vertically because of the extremely varied environmental conditions under which they formed. Individual sedimentary units are often only a few inches thick and rarely exceed 30 feet thick. Sandstones and shales commonly grade laterally into each other, and shales sometimes interfinger and grade into limestones and coals. The underclays, coals, black shales, and some limestones, however, display remarkable lateral continuity for such thin units. Coal seams have been traced in mines, outcrops, and subsurface drill records over areas comprising several states.



General distribution of the four principal lithologies in Pennsylvanian strata of Illinois.



The idealized cyclothem at left (after Willman and Payne, 1942) infers continuous, widespread distribution of individual cyclothem units, at right the model of a typical cyclothem (after Baird and Shabica, 1980) shows the discontinuous nature of many units in a cyclothem.

The rapid and frequent changes in depositional environments during Pennsylvanian time produced regular or cyclical alternations of sandstone, shale, limestone, and coal in response to the shifting shoreline. Each series of alternations, called a cyclothem, consists of several marine and nonmarine rock units that record a complete cycle of marine invasion and retreat. Geologists have determined, after extensive studies of the Pennsylvanian strata in the Midwest, that an "ideally" complete cyclothem consists of ten sedimentary units (see illustration above contrasting the model of an "ideal" cyclothem with a model showing the dynamic relationships between the various members of a typical cyclothem).

Approximately 50 cyclothems have been described in the Illinois Basin but only a few contain all ten units at any given location. Usually one or more are missing because conditions of deposition were more varied than indicated by the "ideal" cyclothem. However, the order of units in each cyclothem is almost always the same: a typical cyclothem includes a basal sandstone overlain by an underclay, coal, black sheety shale, marine limestone, and gray marine shale. In general, the sandstone-underclay-coal-gray shale portion (the lower six units) of each cyclothem is nonmarine: it was deposited as part of the coastal lowlands from which the sea had withdrawn. However, some of the sandstones are entirely or partly marine. The units above the coal and gray shale are marine sediments deposited when the sea advanced over the coastal plain.

Origin of Coal

It is generally accepted that the Pennsylvanian coals originated by the accumulation of vegetable matter, usually in place, beneath the waters of extensive, shallow, fresh-to-brackish swamps. They represent the last-formed deposits of the nonmarine portions of the cyclothems. The swamps occupied vast areas of the coastal lowland, which bordered the shallow Pennsylvanian sea. A luxuriant growth of forest plants, many quite different from the plants of today, flourished in the warm, humid Pennsylvanian climate. (Illinois at that time was near the equator.) The deciduous trees and flowering plants that are common today had not yet evolved. Instead, the jungle-like forests were dominated by giant ancestors of present-day club mosses, horsetails, ferns, conifers, and cycads. The undergrowth also was well developed, consisting of many ferns, fernlike plants, and small club mosses. Most of the plant fossils found in the coals and associated sedimentary rocks show no annual growth rings, suggesting rapid growth rates and lack of seasonal variations in the climate (tropical). Many of the Pennsylvanian plants, such as the seed ferns, eventually became extinct.

Plant debris from the rapidly growing swamp forests — leaves, twigs, branches, and logs — accumulated as thick mats of peat on the floors of the swamps. Normally, vegetable matter rapidly decays by oxidation, forming water, nitrogen, and carbon dioxide. However, the cover of swamp water, which was probably stagnant and low in oxygen, prevented oxidation, and any decay of the peat deposits was due primarily to bacterial action.

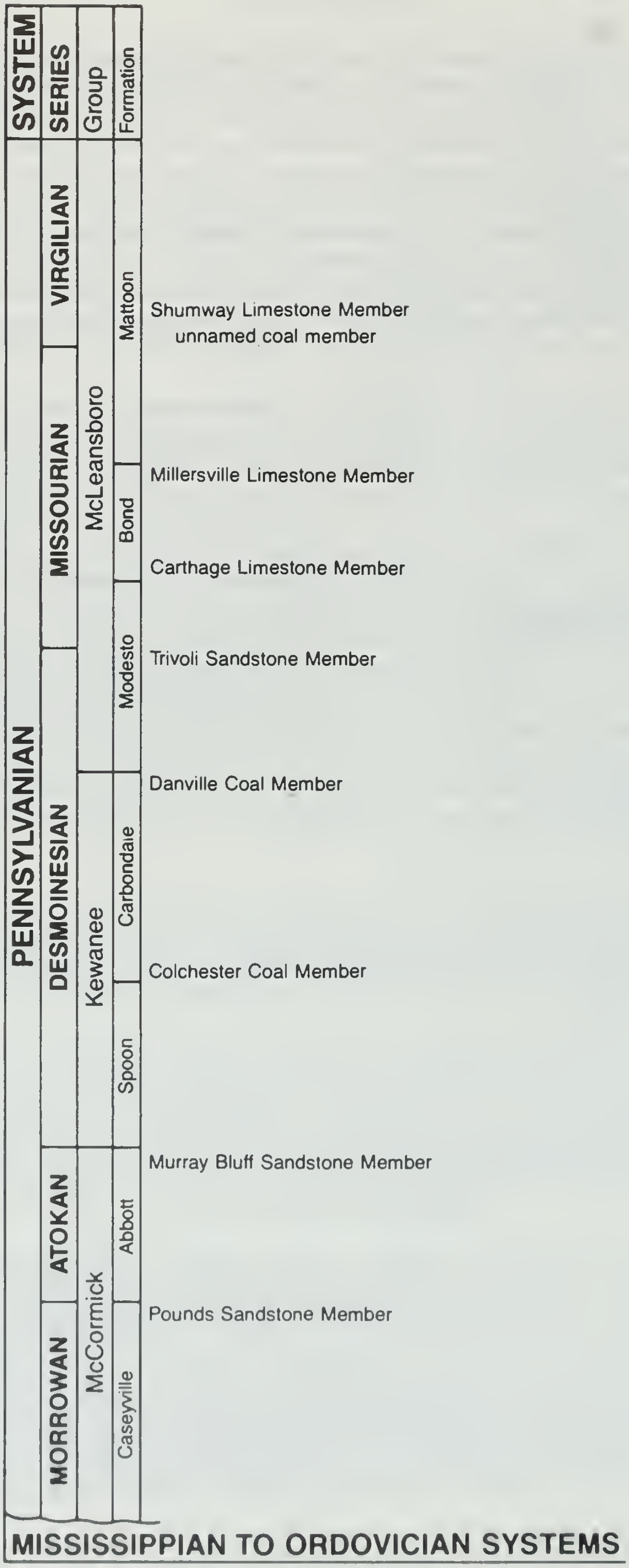
The periodic invasions of the Pennsylvanian sea across the coastal swamps killed the Pennsylvanian forests, and the peat deposits were often buried by marine sediments. After the marine transgressions, peat usually became saturated with sea water containing sulfates and other dissolved minerals. Even the marine sediments being deposited on the top of the drowned peat contained various minerals in solution, including sulfur, which further infiltrated the peat. As a result, the peat developed into a coal that is high in sulfur. However, in a number of areas, nonmarine muds, silts, and sands from the river system on the coastal plain covered the peat where flooding broke through levees or the river changed its coarse. Where these sediments (unit 6 of the cyclothem) are more than 20 feet thick, we find that the coal is low in sulfur, whereas coal found directly beneath marine rocks is high in sulfur. Although the seas did cover the areas where these nonmarine, fluvial sediments covered the peat, the peat was protected from sulfur infiltration by the shielding effect of these thick fluvial sediments.

Following burial, the peat deposits were gradually transformed into coal by slow physical and chemical changes in which pressure (compaction by the enormous weight of overlying sedimentary layers), heat (also due to deep burial), and time were the most important factors. Water and volatile substances (nitrogen, hydrogen, and oxygen) were slowly driven off during the coal-forming ("coalification") process, and the peat deposits were changed into coal.

Coals have been classified by ranks that are based on the degree of coalification. The commonly recognized coals, in order of increasing rank, are (1) brown coal or lignite, (2) sub-bituminous, (3) bituminous, (4) semibituminous, (5) semianthracite, and (6) anthracite. Each increase in rank is characterized by larger amounts of fixed carbon and smaller amounts of oxygen and other volatiles. Hardness of coal also increases with increasing rank. All Illinois coals are classified as bituminous.

Underclays occur beneath most of the coals in Illinois. Because underclays are generally unstratified (unlayered), are leached to a bleached appearance, and generally contain plant roots, many geologists consider that they represent the ancient soils on which the coal-forming plants grew.

The exact origin of the carbonaceous black shale that occurs above many coals is uncertain. Current thinking suggests that the black shale actually represents the deepest part of the marine transgression. Maximum transgression of the sea, coupled with upwelling of ocean water and accumulation of mud and animal remains on an anaerobic ocean floor, led to the deposition of black organic mud over vast areas stretching from Texas to Illinois. Deposition occurred in quiet-water areas where the very fine-grained iron-rich



Generalized stratigraphic column of the Pennsylvanian in Illinois (1 inch = approximately 250 feet)

mud and finely divided plant debris were washed in from the land. Most of the fossils found in black shale represent planktonic (floating) and nektonic (swimming) forms — not benthonic (bottom-dwelling) forms. The depauperate (dwarf) fossil forms sometimes found in black shale formerly were thought to have been forms that were stunted by toxic conditions in the sulfide-rich, oxygen-deficient water of the lagoons. However, study has shown that the "depauperate" fauna consists mostly of normal-size individuals of species that never grew any larger.

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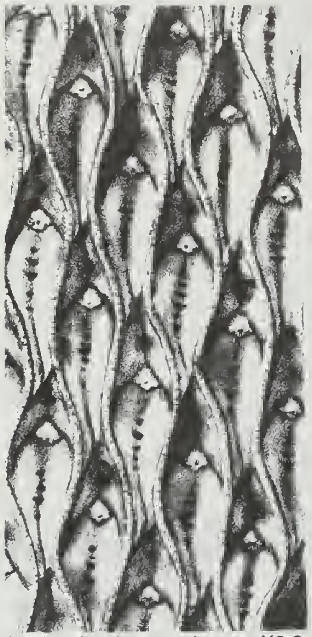
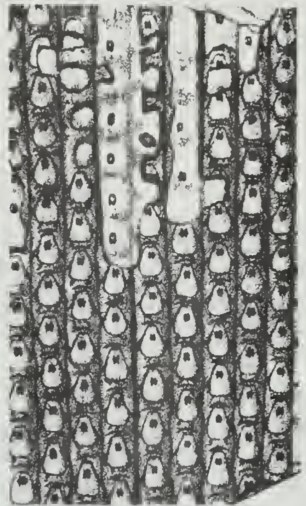
Common Pennsylvanian plants: lycopods, sphenophytes, and ferns

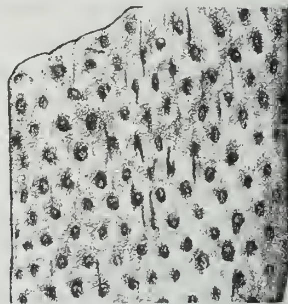


Lepidodendron aculeatum X0.8

Lepidophloios laricinus X0.63



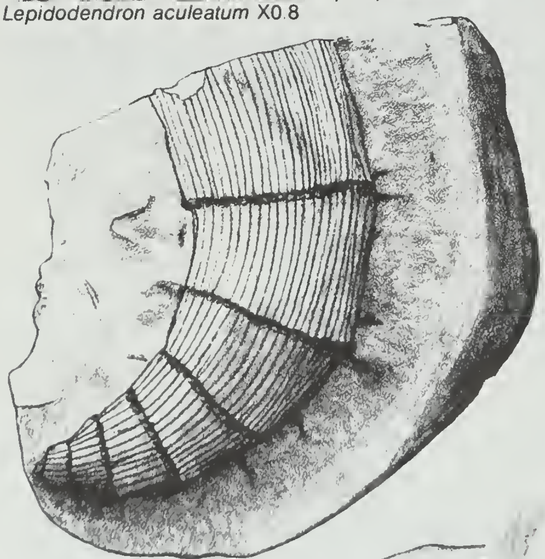
Sigillaria mammilaris X0.5



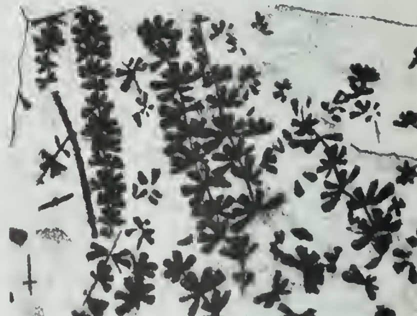
Stigmaria ficoides X0.32

Lepidostrobus ovatifolius X0.8

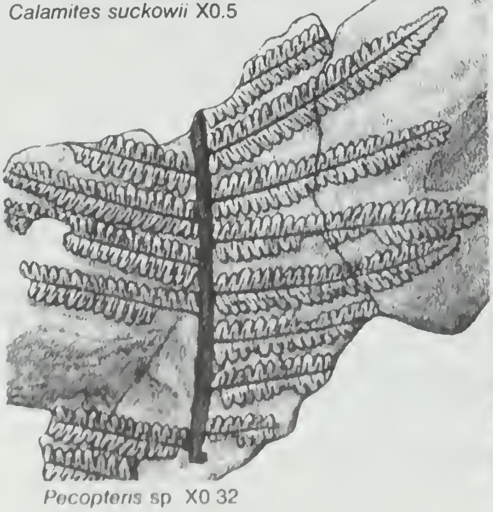
Annularia stellata X0.63



Calamites suckowii X0.5

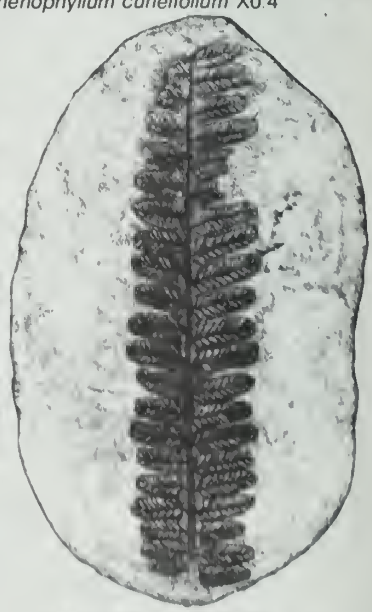


Sphenophyllum cuneifolium X0.4



Pecopteris sp X0 32

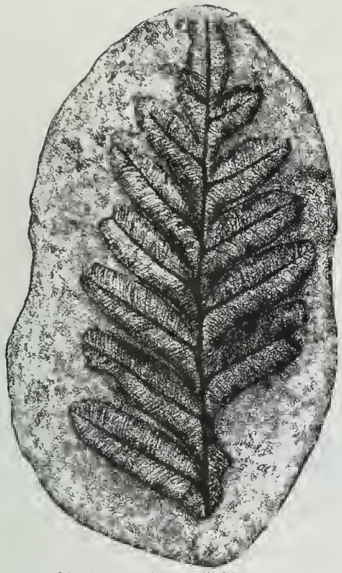
Pecopteris miltonii X2 0



Pecopteris hemitelioides X1 0

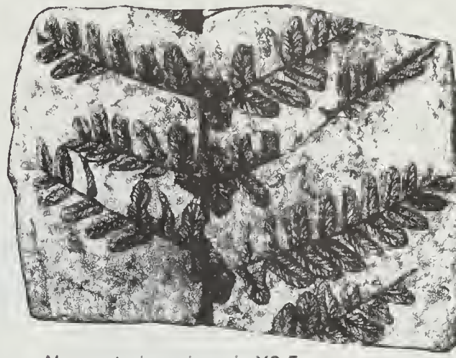
J R Jennings, ISGS

Common Pennsylvanian plants: seed ferns and cordaiteans



Alethopteris serlii X0.63

Alethopteris ambigua X0.63



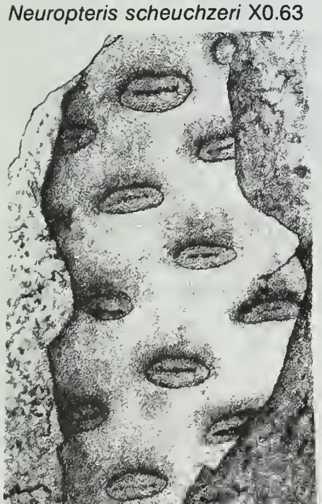
Neuropteris rarinervis X0.5

Mariopteris nervosa X0.8

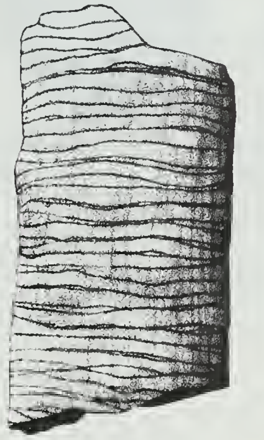
Neuropteris scheuchzeri X0.63

Sphenopteris rotundiloba X0.8

Trigonocarpus parkinsonii X1.25



Cordaicladus sp. X1.0



Artisia transversa X0.63

Cordaicarpon major X2.0

Cordaites principalis X0.63

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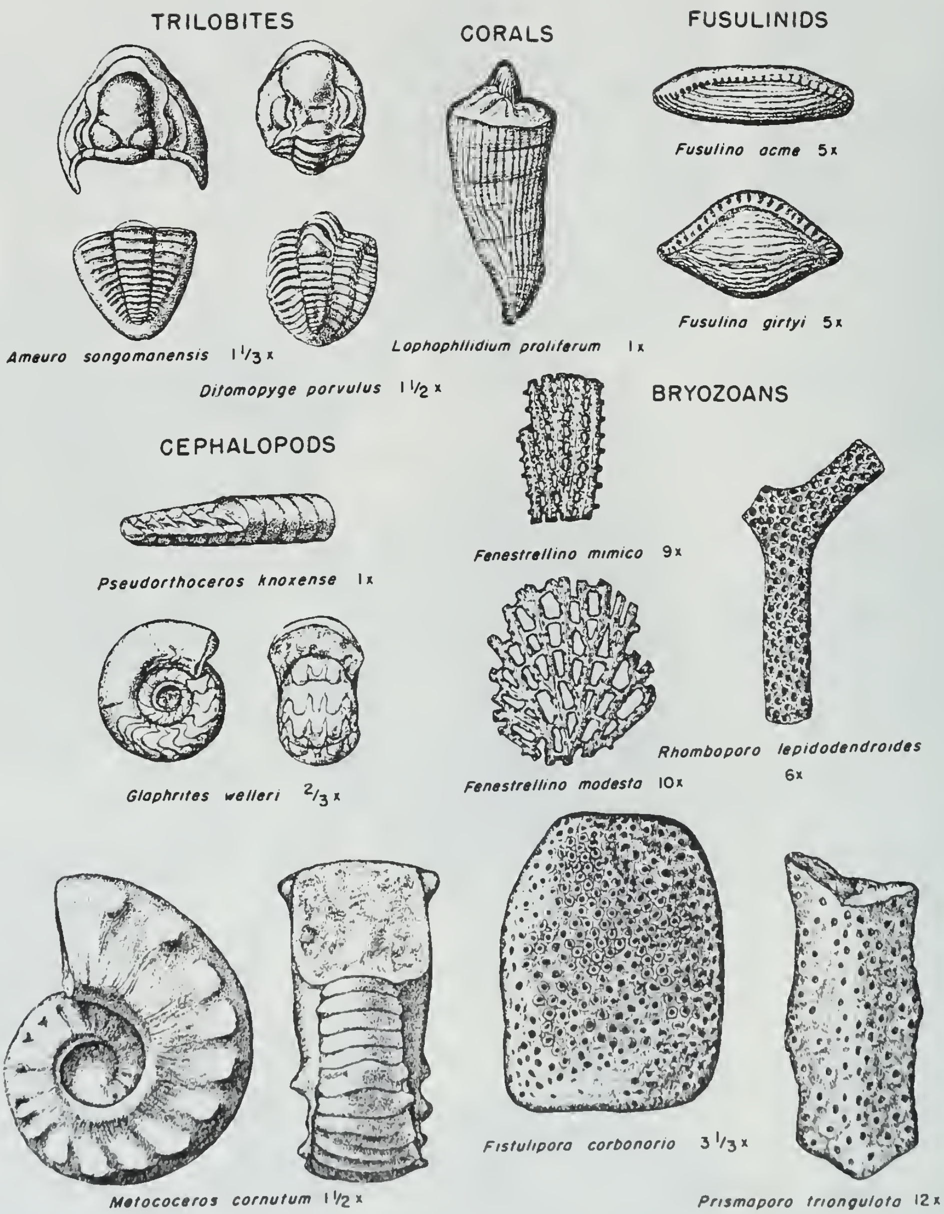

TRILOBITES
CORALS
FUSULINIDS
Fusulina acme 5x
Fusulina girtyi 5x
Ameura sangamonensis 1 1/3 x
Lophophyllidium proliferum 1x
Ditomopyge parvulus 1 1/2 x
BRYOZOANS
CEPHALOPODS
Fenestrellina mimica 9x
Pseudorthoceras knoxense 1x
Rhombopora lepidodendroides 6x
Fenestrellina modesta 10x
Glaphrites welleri 2/3 x
Fistulipora carbonaria 3 1/3 x
Metacoceras cornutum 1 1/2 x
Prismopora triangulata 12x

PELECYPODS

Nucula (Nuculopsis) girtyi 1x

Edmonia ovata 2x

Astartella concentrica 1x

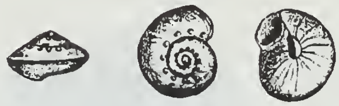
Dunbarella knighti 1 1/2 x

Cardiomorpha missouriensis "Type A" 1x

Cardiomorpha missouriensis "Type B" 1 1/2 x

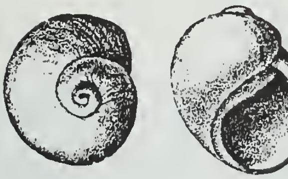
GASTROPODS

Euphemites carbonarius 1 1/2 x



Trepospira illinoisensis 1 1/2 x

Donaldina robusta 8x



Naticopsis (Jedria) ventricosa 1 1/2 x

Trepospira sphaerulata 1x

Knightites montfortianus 2x

Glabrocingulum (Glabrocingulum) grayvillense 3x

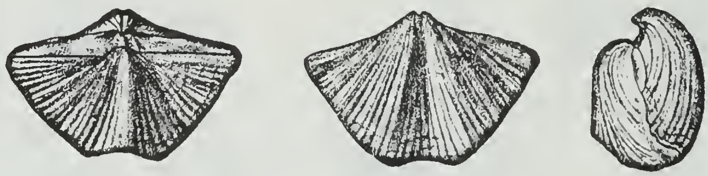
BRACHIOPODS

Wellerella tetrahedra 1½ x

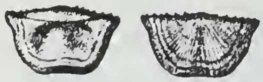
Juresonia nebrascensis 2/3 x

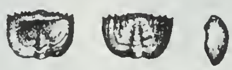
Derbya crassa 1x

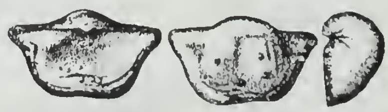
Composita argentea 1x



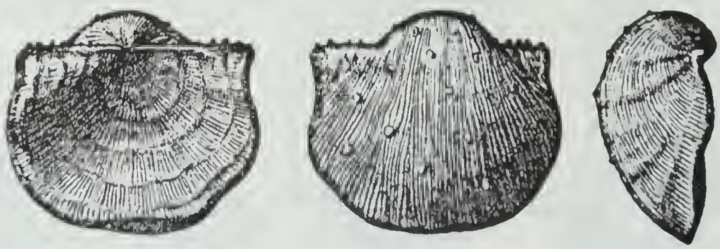
Neospirifer cameratus 1x







Chonetes granulifer 1½ x *Mesolobus mesolobus* var. *euampygus* 2x *Marginifera splendens* 1x



Crurithyris planoconvexa 2x

Linoproductus "cora" 1x

ILLINOIS STATE GEOLOGICAL SURVEY
Urbana, Illinois 61801

GEOGRAM 2
October 1974

ERRATICS ARE ERRATIC

Myrna M. Killey

You may have seen them scattered here and there in Illinois—boulders, some large, some small, lying alone or with a few companions in the corner of a field, at the edge of a road, in someone's yard, or perhaps on a courthouse lawn or schoolyard. Many of them seem out of place, like rough, alien monuments in the stoneless, grassy knolls and prairies of our state. Some—the colorful and glittering granites, banded gneisses, and other intricately veined and streaked igneous and metamorphic rocks—are indeed foreign rocks, for they came from Canada and the states north of us. Others—gray and tan sedimentary rocks—are native rocks and may be no more than a few miles from their place of origin. All of these rocks are glacial boulders that were moved to their present sites by massive ice sheets that flowed across our state. If these boulders are unlike the rocks in the quarries and outcrops in the region where they are found, they are called erratics.

The continental glaciers of the Great Ice Age scoured and scraped the land surface as they advanced, pushing up chunks of bedrock and grinding them against each other or along the ground surface as the rock-laden ice sheets pushed southward. Hundreds of miles of such grinding, even on such hard rocks as granite, eventually rounded off the sharp edges of these passengers in the ice until they became the rounded, irregular boulders we see today. Although we do not know the precise manner in which erratics reached their present isolated sites, many were probably dropped directly from the melting front of a glacier. Others may have been rafted to their present resting places by icebergs on ancient lakes or on the floodwaters of some long-vanished stream as it poured from a glacier. Still others, buried in the glacial deposits, could have worked their way up to the land surface as the surrounding loose soil repeatedly froze and thawed. When the freezing ground expands, pieces of rock tend to be pushed upward, where they are more easily reached by the farmer's plow and also more likely to be exposed by erosion.

An eight-foot boulder of pink granite left by a glacier in the bed of a creek about 5 miles southwest of Alexis, Warren County, Illinois. (From ISGS Bulletin 57, 1929.)

Generally speaking, erratics found northeast of a line drawn from Freeport in Stephenson County, southward through Peoria, and then southeastward through Shelbyville to Marshall at the east edge of the state were brought in by the last glacier to enter Illinois. This glaciation, called the Wisconsinan, spread southwestward into Illinois from a center in eastern Canada, reaching our state about 75,000 years ago and (after repeated advances and retreats of the ice margin) melting from the state about 12,500 years ago. Erratics to the west or south of the great arc outlined above were brought in by a much older glacier, the Illinoian, which spread over most of the state about 300,000 to 175,000 years ago. Some erratics were brought in by even older glaciers that came from the northwest.

You may be able to locate some erratics in your neighborhood. Sometimes it is possible to tell where the rock originally came from by determining the kind of rock it is. A large boulder of granite, gneiss, or other igneous or metamorphic rock may have come from the Canadian Shield, a vast area in central and eastern Canada where rocks of Precambrian age (more than 600 million years old) are exposed at the surface. Some erratics containing flecks of copper were probably transported here from the "Copper Range" of the upper peninsula of Michigan. Large pieces of copper have been found in glacial deposits of central and northern Illinois. Light gray to white quartzite boulders with beautiful, rounded pebbles of red jasper came from a very small outcrop area near Bruce Mines, Ontario, Canada. Purplish pieces of quartzite, some of them banded, probably originated in the Baraboo Range of central Wisconsin. Most interesting of all are the few large boulders of Canadian tillite. Tillite is lithified (hardened into rock) glacial till deposited by a Precambrian glacier many millions of years older than the ones that invaded our state a mere few thousand years ago. Glacial till is an unsorted and unlayered mixture of clay, sand, gravel, and boulders that vary widely in size and shape. Tillite is a gray to greenish gray rock containing a mixture of grains of different sizes and scattered pebbles of various types and sizes.

Many erratics are of notable size and beauty, and in parts of Illinois they are commonly used in landscaping. Some are used as monuments in courthouse squares, in parks, or along highways. Many are marked with metal plaques to indicate an interesting historical spot or event. Keep an eye out for erratics. There may be some of these glacial strangers in your neighborhood that would be interesting to know.

GEOGRAM 5
October 1975

ANCIENT DUST STORMS IN ILLINOIS

Myrna M. Killey

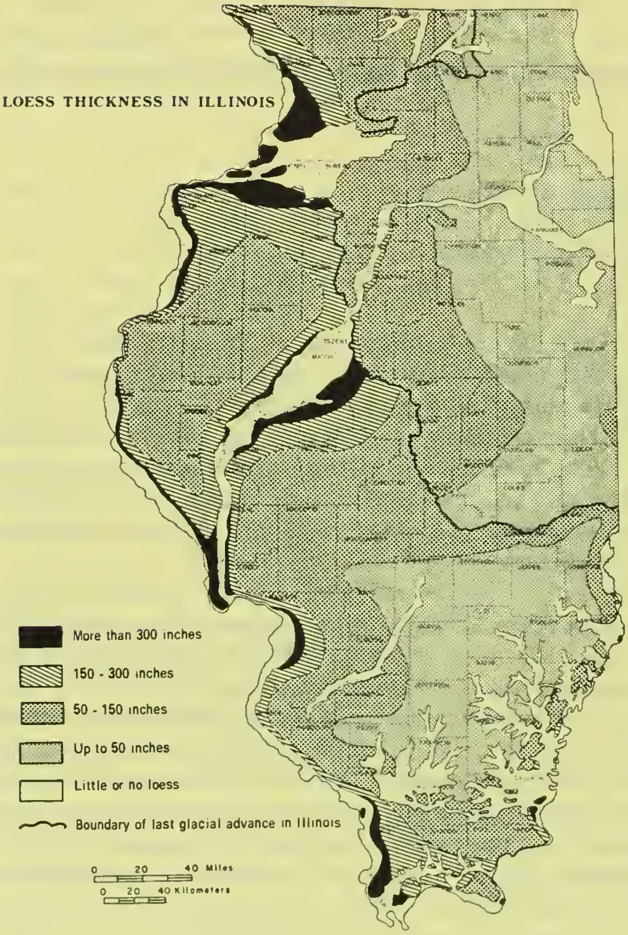
Fierce dust storms whirled across Illinois long before human beings were here to record them. Where did all the dust come from? Geologists have carefully put together clues from the earth itself to get the story. As the glaciers of the Great Ice Age scraped and scoured their way southward across the landscape from Canada, they moved colossal amounts of rock and earth. Much of the rock ground from the surface was kneaded into the ice and carried along, often for hundreds of miles. The glaciers acted as giant grist mills, grinding much of the rock and earth to "flour"—very fine dust-sized particles.

During the warm seasons, water from the melting ice poured from the glacier front, laden with this rock flour, called silt. In the cold months the meltwater stopped flowing and the silt was left along the channels the water had followed, where it dried out and became dust. Strong winds picked up the dust, swept it from the floodplains, and carried it to adjacent uplands. There the forests along the river valleys trapped the dust, which became part of the moist forest soil. With each storm more material accumulated until the high bluffs adjacent to major rivers were formed. The dust deposits are thicker along the eastern sides of the valleys than they are on the western sides, a fact from which geologists deduce that the prevailing winds of that time blew from west to east, the same direction as those of today. From such clues geologists conclude that the geologic processes of the past were much like those of today.

The deposits of windblown silt are called loess (rhymes with "bus"). Loess is found not only in the areas once covered by the glaciers but has been blown into the nonglaciated areas. The glaciers, therefore, influenced the present land surface well beyond the line of their farthest advance.

Loess has several interesting characteristics. Its texture is so fine and uniform that it can easily be identified in roadcuts—and because it blankets such a vast area many roads are cut through it. Even more noticeable is its tendency to stand in vertical walls. These steep walls develop as the loess drains and becomes tough, compact, and massive, much like a rock. Sometimes cracks develop in the loess, just as they do in massive limestones and sandstones. Loess makes good highway banks if it is cut vertically. A vertical cut permits maximum drainage because little surface is exposed to rain, and rainwater tends to drain straight down through it to the rock underneath. If the bank is cut at an angle more water soaks in, which causes the loess to slump down. Along Illinois roads the difference between a loess roadcut and one in ordinary glacial till is obvious. The loess has a very uniform texture, while the till is composed of a random mixture of rock debris, from clay and silt through cobbles and boulders.

Many loess deposits are worth a close look. Through a 10-power hand lens separate grains can be seen, among them many clear, glassy, quartz grains. Some loess deposits contain numerous rounded, lumpy stones called concretions. Their formation began when water percolating through the loess dissolved tiny



limestone grains. Some of the dissolved minerals later became solid again, gathering around a tiny nucleus or along roots to form the lumpy masses. A few such concretions are shaped roughly like small dolls and, from this resemblance, are called "loess kindchen," a German term meaning "loess children." They may be partly hollow and contain smaller lumps that make them rattle when shaken.

Fossil snails can be found in some loess deposits. The snails lived on the river bluffs while the loess was being deposited and were buried by the dust. When they are abundant, they are used to determine how old the loess is. The age is found by measuring the amount of radioactive carbon in the calcium carbonate of their shells.

Some of the early loess deposits were covered by new layers of loess following later glacial invasions. Many thousands of years passed between the major glacial periods, during which time the climate was as warm as that of today. During the warm intervals, the surface of the loess and other glacial deposits was exposed to weather. Soils developed on most of the terrain, altering the composition, color, and texture of the glacial material. During later advances of the ice, some of these soils were destroyed, but in many places they are preserved under the younger sediments. Such ancient buried soils can be used to determine when the materials above and below them were laid down by the ice and what changes in climate took place.

The blanket of loess deposited by the ancient dust storms forms the parent material of the rich, deep soils that today are basic to the state's agriculture. A soil made of loess crumbles easily and has great moisture-holding capacity. It also is free from rocks that might complicate cultivation. Those great dust storms that swirled over the land many thousands of years ago thus endowed Illinois with one of its greatest resources, its highly productive soil.

ILLINOIS STATE GEOLOGICAL SURVEY
Urbana, Illinois 61801

GEOGRAM 6
October 1975

DO YOU LIVE ABOVE AN UNDERGROUND RIVER?

Myrna M. Killey

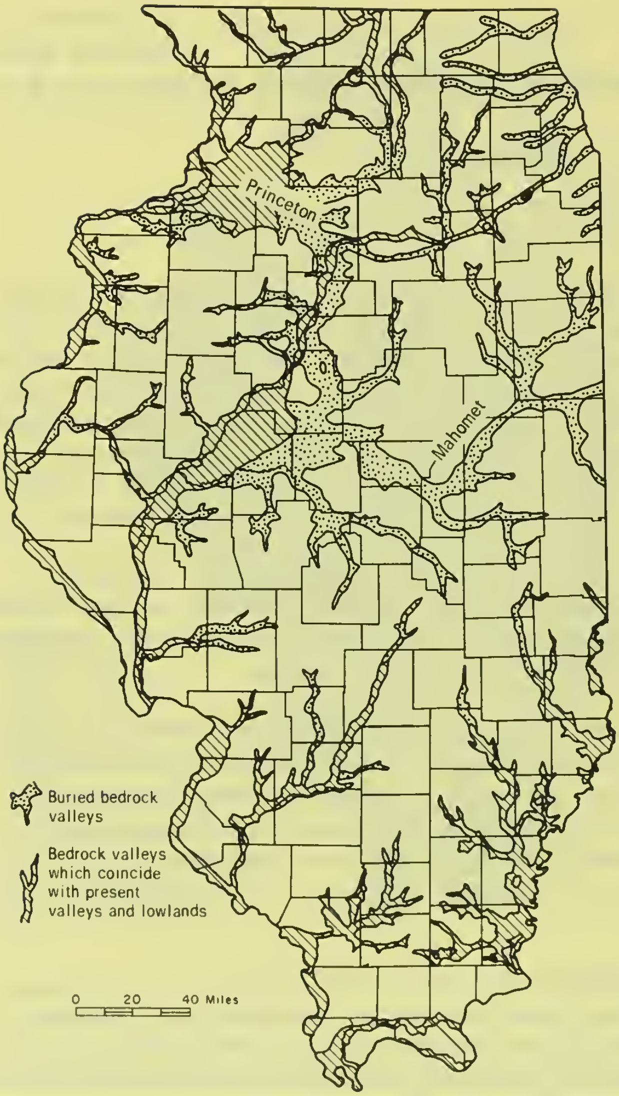
Do you think of an underground river as a hidden stream rushing through a tunnel in solid rock? Such subterranean rivers do exist in some states—in Alabama and Missouri, for example. In Illinois, however, except in a few areas where water flows through cracks and channels it has created by dissolving the limestone bedrock, underground "rivers" are not really rivers at all. The Mahomet "river" that underlies part of east-central Illinois is a good example. So is the eastern part of this "river," which is called the Teays (rhymes with "days"). Such rivers are vital to many towns, for they are a reliable source of water.

The Mahomet-Teays river system was discovered more than 25 years ago when numerous water wells were drilled in the eastern and midwestern United States. The story of this vast river system has been pieced together largely from information obtained from records made during the drilling of the wells.

More than a million years ago, before the glaciers of the Great Ice Age crept down over the Midwest, a river as large as the present Mississippi flowed generally westward from its probable source in the mountains of West Virginia, crossed Ohio and Indiana, and traversed east-central Illinois from Hoopeston to Havana. At Havana it joined another ancient river system that occupied what is now the Illinois River Valley (see map). All along its course it cut a deep valley in the bedrock.

When the successive glaciers invaded Illinois from Canada, the fringes of the ice melted during the warmer periods, and the water (meltwater) carried with it great quantities of sand and gravel that had been embedded in the ice. This material, called *outwash*, was deposited in thick layers in the Mahomet Valley. As the later glaciers advanced southward, both the valley and its outwash were buried by ice. When the ice finally melted, tremendous amounts of unsorted rock debris (pebbly, sandy clay called *till*) that had been held in the ice blanketed the land surface, including the former river valley, to depths of 50 to more than 100 feet. (The outwash and till deposits are collectively called *drift*.) The great Mahomet River Valley was obliterated from the landscape and the river no longer existed. Instead, on the new land surface the river patterns we know today developed.

The buried Mahomet Valley is invaluable to east-central Illinois because its porous sand and gravel deposits act as vast underground sponges, storing the rainwater that seeps downward from the land surface. Water flows easily through the sand and gravel into wells drilled in the porous materials. In contrast, glacial till is too fine-grained to allow the water it holds to flow easily and, therefore, cannot supply large amounts of water to wells. Towns such as Hoopeston, Champaign-Urbana, Mahomet, Monticello, and Clinton that are situated above the buried Mahomet Valley have large ground-water supplies available to them, but towns away from the valley have more difficulty obtaining their water. Perhaps the term "underground river" is still applied to the Mahomet Valley because it is easier to imagine great volumes of well water coming from a river than from beds of sand and gravel in a buried valley.



The Mahomet Valley has been traced for about 150 miles across Illinois, it lies at an average depth of more than 200 feet below land surface, and its bottom is at an average elevation of 350 feet above sea level. In some places the ancient valley varies in width from 5 miles at the Indiana line to almost 10 miles near Clinton in De Witt County.

Another major "underground river" is the Princeton Bedrock Valley in the north-central part of Illinois. Many smaller bedrock valleys in the state contain sand and gravel deposited by glacial meltwater. The Mississippi, Illinois, Kaskaskia, and Wabash Rivers also contain beds of outwash deposited by glacial meltwaters, but their courses were not obliterated by the glaciers, and their valleys have remained open as drainageways.

The water supplies in these deposits in the ancient river valleys of Illinois are one of many resources contributing to the state's natural wealth. Of the 3.3 billion gallons of water a day used by Illinois, about 450 million gallons are pumped from sand and gravel deposits, mainly of glacial origin. The value of ground water from these deposits is over $115 million per year.

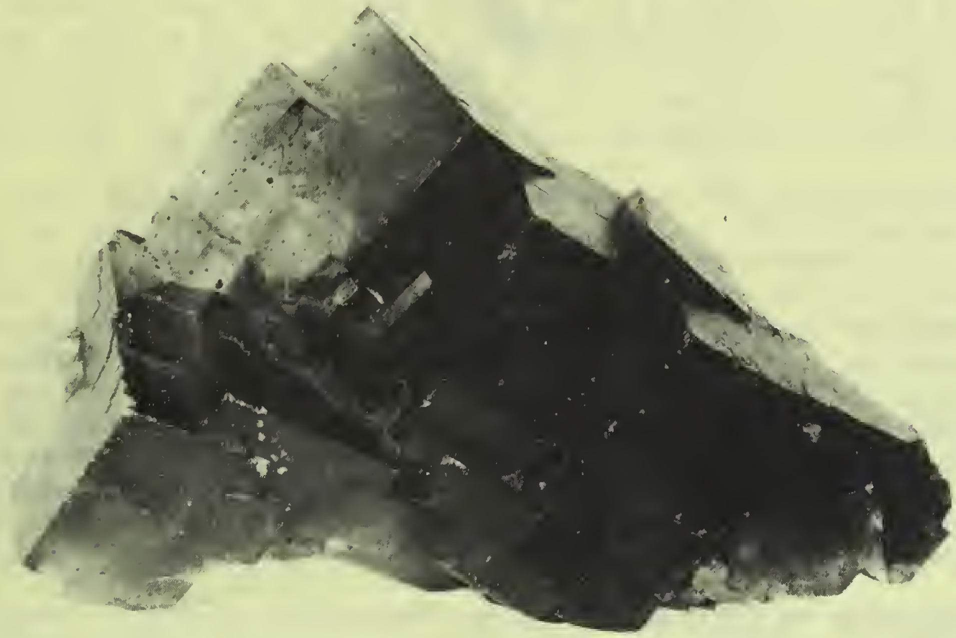
Do you live above an underground "river"? Look at the map and see. Locate the source of the water you use in your town. If you should see a well being drilled, stop and ask if you can look at the earth materials brought up from the well. These are the kinds of material used to interpret the geologic history of Illinois.

ILLINOIS STATE GEOLOGICAL SURVEY
Champaign, Illinois 61820

GEOGRAM 9
July 1984

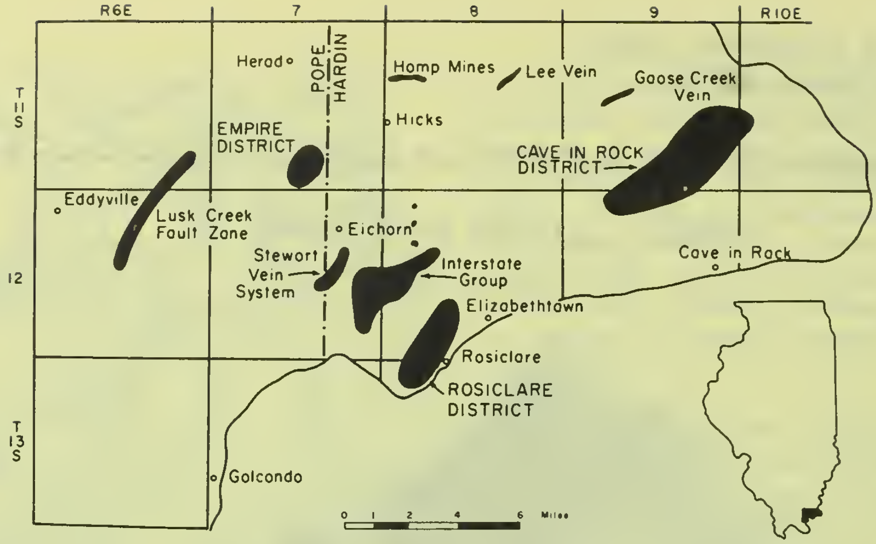
FLUORITE: ILLINOIS STATE MINERAL

David L. Reinertsen



Fluorite, or fluorspar as miners and geologists call it, is a calcium fluoride (CaF_2) mineral. This transparent to translucent, glassy-appearing mineral is usually found as irregular masses in vein and bedding-replacement deposits in Pope and Hardin Counties in southeastern Illinois. At times, however, beautiful cubic crystals (such as those pictured) are found. The color of fluorite is variable—commonly gray or yellowish-white, but sometimes purple, yellow, blue, pure white, colorless, or green. Some varieties of fluorite glow in invisible ultraviolet light, from which the term "fluorescence" is derived. Fluorite is sometimes called a gemstone because of the high light reflectance from its crystal faces and the high polish that can be given to these faces and the cleavage surfaces. But its brittleness and relative softness make fluorite unsuitable for ring settings; brooches and pendants must be handled very carefully so that the specimens in their settings are not scratched or fractured.

Bedrock strata deposited during the Mississippian Period of geologic time (about 330 million years ago) contain the fluorspar deposits of extreme southeastern Illinois. Complex faulting of this region about 270 million years ago produced the open fractures along which fluorspar later was deposited. The time of fluorspar deposition and the exact origin of the mineralizing solutions that formed the vein and bedded ores are unknown. Presumably, the ores were deposited by hot, fluorine-bearing, aqueous solutions rising from deep within the earth's crust. Rocks of Mississippian age found in prospect drill holes elsewhere in southern Illinois contain occasional thin streaks of fluorite, but no other evidence indicates economically important deposits outside of the southeastern Illinois fluorspar district.



Principal fluorspar mining districts in the extreme southern Illinois region.

Although early Illinois Indians made artifacts from fluorspar, the first recorded use of fluorspar was in 1823, when material from Shawneetown was used to manufacture hydrofluoric acid. The discovery of fluorspar and galena near Rosiclare in 1842 resulted in the first known mining operation in the Illinois fluorspar district. Galena, the ore of lead, was the principal mineral sought and recovered, and the fluorspar was generally discarded as waste because of its limited market. Shipments of fluorspar from the district did not begin until the early 1870s.

The state legislature designated fluorite as the state mineral of Illinois in 1965. Although other industrial minerals in Illinois have a higher annual production value than fluorite, these minerals are mined throughout the United States. Fluorite, on the other hand, is found in only a few localities in our country; consequently, the mining of fluorite has become a multimillion dollar per year industry in Illinois. Illinois became the leading producer of fluorspar in the country in 1942, and for many years has accounted for more than 50 percent of the total United States production. However, because of competition from foreign fluorspar producers, profit from the Illinois mines frequently results from the sale of recovered associated minerals such as sphalerite (zinc ore), barite, and silver.

Today, high priority uses of fluorspar include the manufacture of steel, metal alloys, glass, enamel glazes, and use in water fluoridation. The chemical industry is the largest consumer of fluorspar, mostly for the manufacture of hydrofluoric acid. This acid is used in the production of aluminum, gasoline, nuclear power, chemicals, rocket fuels, metal plating, uranium, drugs, and organic and inorganic fluorides. Inorganic fluorides are used in toothpastes, special fluxes, optical lenses, and concrete hardeners; organic fluorides, for the production of plastics, refrigerants, non-stick coatings, herbicides, fire extinguishers, lubricants, stain repellents, anesthetics, degreasing agents, medicinals, astronautical equipment, cleaning solvents, cooling liquids, dyes, space guidance systems, and foaming agents.

Fluorspar has a challenging future for new and varied industrial uses. The Illinois State Geological Survey pursues an active program of fluorine research that is directed toward better utilization of this mineral.

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PREFACE

The mineral resources of the U. S. midcontinent were instrumental in the development of the U. S. Mineral resources are an important and essential component of the current economy and will continue to play a vital role in the future. Mineral resources provide essential raw materials for the goods consumed by industry and the public. To ensure the availability of mineral resources and contribute to the ability to locate and define mineral resources, the U.S. Geological Survey (USGS) has undertaken two programs in cooperation with the State Geological Surveys in the midcontinent region.

In 1975, under the Conterminous U.S. Mineral Assessment Program (CUSMAP) work began on the Rolla 1° X 2° Quadrangle at a scale of 1:250,000 and was continued in the adjacent Springfield, Harrison, Joplin, and Paducah quadrangles across southern Missouri, Kansas, Illinois, Arkansas and Oklahoma. Public meetings were held in 1981 to present results from the Rolla CUSMAP and in 1985 for the Springfield CUSMAP.

In 1984, the Midcontinent Strategic and Critical Minerals Project (SCMP) was initiated by the USGS and the State Geological Surveys of 16 states to map and compile data at 1:1,000,000 scale and conduct related topical studies for the area from latitude 36° to 46°N. and from longitude 88° to 100°W. Precambrian basement compilations for the SCMP were extended even farther north and west.

In an effort to reach a larger number of those who might be interested in midcontinent mineral resource data and research, a symposium, patterned after the U.S.G.S. McKelvey Forums was held at St. Louis, Missouri, April 1989. The purpose of the meeting was to present summaries or progress reports on the regional compilations and topical research done during the first five years of the SCMP midcontinent project and more detailed reports on the geology, stratigraphy, sedimentology, geochemistry, geophysics and mineral-resource potential of the Harrison and Joplin 1° X 2° quadrangles. The first results and status of the Paducah CUSMAP were presented at this meeting. Progress reports on the CUSMAP and SCMP projects were presented and continue to be presented at various national and regional meetings.

Plans to undertake the assessment of the mineral resource potential of the Paducah Quadrangle were approved in 1985 and work by the USGS, the Illinois State Geological Survey (ISGS), the Kentucky Geological Survey, the Missouri Division of Geology and Land Survey, and the Indiana Geological Survey began in 1987. In 1986, a joint USGS/ISGS pilot study extended the insoluble residue analysis methods developed for the Rolla Quadrangle to a traverse of core and rotary drill holes along western Illinois and across the Paducah Quadrangle. Results from this traverse indicate that the mineralization documented on the east side of the Ozark Uplift on the Rolla Quadrangle extended into the Illinois Basin.

The Illinois State Geological Survey, the Indiana Geological Survey and the Kentucky Geological Survey formed the Illinois Basin Consortium (IBC) in 1989 to foster cooperative research projects on basin-wide geologic and mineral resource-related problems. The USGS Evolution of Sedimentary Basins Program

has undertaken a number of research projects on the Illinois Basin that complement the IBC program.

Results from the Paducah CUSMAP resource evaluation and topical studies and the IBC and USGS Evolution of Sedimentary Basin studies are presented in this open file abstract volume. This volume contains the program and abstracts from the January 1992 St. Louis Paducah-IBC meeting. The abstracts are arranged in alphabetical order by the first author's name.

This symposium on the Paducah CUSMAP and IBC efforts presents the results of cooperative research programs that utilized the talent, equipment and other resources of the federal and state geological surveys. Without this federal-state cooperation, this assessment could not have taken place. This open file volume records the contributions of these organizations:

U. S. Geological Survey
Illinois State Geological Survey
Kentucky Geological Survey
Missouri Division of Geology and Land Survey
Indiana Geological Survey

The USGS and State Geological Surveys welcome discussions from our colleagues in industry and academia.

Marty Goldhaber
Jim Eidel

BLR:CUSMAP\PREFACE.CUS

COOPERATIVE GEOLOGIC MAPPING PROGRAM IN SOUTHERN ILLINOIS

Background

The southern Illinois region, while rich in some areas in mineral resources, especially coal, oil and gas and fluorspar, is underdeveloped. The geology of the southernmost portion of the region is more complex than other parts of the state, and its details are only now beginning to be understood. In 1981, the Illinois State Geological Survey (ISGS), a division of the Department of Energy and Natural Resources (ENR), undertook a program of detailed geological mapping in southern Illinois with support from the Nuclear Regulatory Commission (NRC). Mapping in the area was renewed in 1984 with federal matching funds from the Cooperative Geologic Mapping Program (COGEOMAP) of the U.S. Geological Survey (USGS) and with state appropriations for this new initiative. The area being mapped extends northward and westward from the southeastern Illinois Fluorspar Mining District, mapped by the Survey's scientists 20 years ago.

Geologic mapping by the ISGS' geologists at a scale of 1:24,000 (one inch equals 2,000 feet) revealed extensive fault zones in the region but no evidence of modern rejuvenation that would suggest the potential for damage to nuclear power plants in the event of a New Madrid earthquake. Instead, the Survey's geologists found new details about the geology of the region that were broadly encouraging for mineral resource exploration. Faults outside the Illinois Fluorspar Mining District have been mapped in detail and are potential targets for mineral exploration. Renewed efforts by the Survey's mappers have located new seams of coal. However, these are generally thinner and less easily mined than other coals in the state, and their sulfur content is moderate to high. Detailed mapping also is changing geologic concepts of the region in ways that could provide new tools for successful oil and gas exploration.

Since the mid-1980s, the ISGS, through COGEOMAP, has completed and published nine 7.5-minute quadrangle maps in southern Illinois. An additional 11 maps are in various stages of production. In FY92, field mapping of four quadrangles is under way. The program also has been expanded to include research into the methodology for presenting maps that show the subsurface variation in thickness and character of surficial deposits. The result of this effort will be a 1:100,000-scale (one inch equals 1.6 miles) map of the Champaign 30′ x 60′ Quadrangle in central Illinois.

The USGS has obtained up to $2.7 million annually to support the nationwide COGEOMAP program since federal FY85. For federal FY92, the program in Illinois receives $105,000 in direct federal support and $15,000 in additional in-kind services from the USGS. This federal support is matched by the state-supported mapping program at the ISGS. The Illinois COGEOMAP program is an excellent example of successful cooperation between the USGS and State Geological Surveys to address the pressing need for a national geologic mapping program.

Benefits

In a $23-million program supported by state and federal funds over about 18 years, the Commonwealth of Kentucky cooperated with the USGS to complete detailed geologic maps of the entire state. Officials from Kentucky and the USGS estimate that the cost of the mapping program has been repaid 50 times over through discovery of new resources, reduction in construction and engineering costs, attraction of new businesses, and avoidance of geologic hazards.

Benefits of detailed geologic mapping have also been quantified by the ISGS in a definitive study for Boone and Winnebago counties. Benefits, calculated from avoided costs associated with the clean up of landfills and industrial disposal sites, were compared to the cost of mapping. The return on an investment of $300,000 in 1990 dollars was about 23 to 54 times the investment for the best-case scenario, and five to 11 times the investment for the worst-case scenario. The most probable case indicated benefit/cost ratios of 11.7 to 27.2. The benefit/cost analysis excludes other benefits that are not currently quantifiable such as identifying and recovering natural resources and providing basic data to industry and government for siting facilities--data indicating water supplies, foundation conditions, and areas suitable for the installation of septic tanks. These benefits would increase the benefit/cost ratios significantly.

SM2/92

MINERAL ASSESSMENT PROGRAM FOR SOUTHERN ILLINOIS

Background

The Conterminous U.S. Mineral Assessment Program (CUSMAP) of the U.S. Geological Survey (USGS), carried out in cooperation with state geological agencies, provides for detailed geological, geochemical and geophysical (seismic) studies in regions known to contain or have potential for mineral deposits. The purpose is to develop sufficient knowledge to determine the likelihood of finding new mineral resources or extensions of known deposits. A CUSMAP study of the Paducah 1 X 2 degree quadrangle, covering approximately 7,500 square miles in southern Illinois and adjacent parts of Missouri, Kentucky and Indiana, was begun in the Fall of 1986 as a cooperative effort of the USGS; the Illinois State Geological Survey (ISGS), a division of the Department of Energy and Natural Resources; and the State Geological Surveys of Missouri, Kentucky and Indiana.

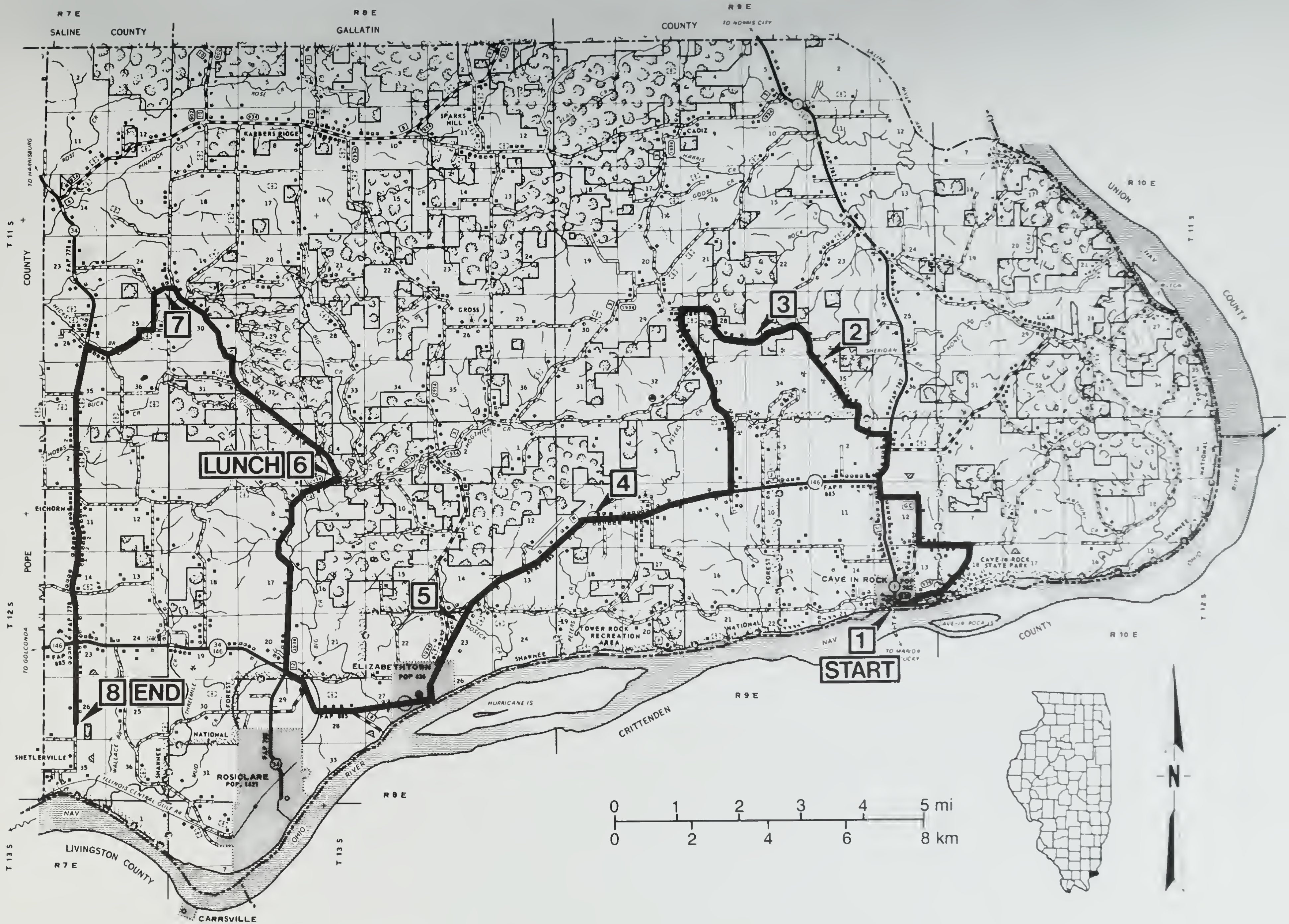
The Paducah quadrangle includes significant numbers of active and inactive mines (fluorspar, lead, zinc and barite); extensive quarries and pits for extraction of limestone, sand, gravel, silica and clay; active coal mines; and producing oil fields. The Illinois-Kentucky Fluorspar District in Hardin and Pope counties has accounted for as much as 90 percent of U.S. domestic fluorspar production. The quadrangle lies just east of the world-class southeast Missouri Lead District and, based on recent preliminary subsurface geochemical surveys and known minor surface occurrences of ore minerals, appears to hold potential for deep lead and zinc sulfide mineralization.

The CUSMAP evaluation of the Paducah quadrangle is being made on the basis of ongoing studies that include: 1) compilation and evaluation of pre-existing geological, geochemical and seismic data; 2) new geological mapping, geochemical analysis and geophysical measurements to expand the data base and test new hypotheses; 3) topical studies on the origin and development of coal, oil, gas, and non-fuel (metallic and non-metallic) mineral resources; and 4) based on the data gathered, an appraisal of the potential for the discovery of additional mineral wealth. The ISGS is coordinating much of this research effort and data input from the states and, with the USGS, is taking the lead in developing an Illinois Geographic Information System (IGIS) data base that incorporates new techniques in computerized spatial data analysis and cartography. The efficacy of the IGIS for assessing mineral potential was demonstrated in April 1991 at a workshop held in Champaign.

Research and data acquisition for the Paducah CUSMAP project is completed; maps have been prepared showing areas of high, moderate, and low potential and high, moderate and low confidence for mineral discovery. Results of the assessment will be released in early 1992.

Benefits

A series of reports on the geology and mineral resources of the Paducah 1 X 2 degree quadrangle will be prepared upon completion of the CUSMAP project. These will include new and innovative compilations of resource data related to coal, oil, gas, and the industrial mineral and metal resources; detailed surficial, bedrock and subsurface maps and cross sections; topical studies; and a general assessment of the mineral potential of the area. Availability of published and open-file data, coupled with the development of new theories and models, could make southern Illinois more attractive for mineral exploration and entrepreneurial activity.



SALINE COUNTY
GALLATIN COUNTY
POPE COUNTY
LIVINGSTON COUNTY
CRITTENDEN COUNTY
UNION COUNTY
R 7 E
R 8 E
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T 11 S
T 12 S
T 13 S
TO HARRISBURG
TO NORRIS CITY
TO GOLCONDA
START
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LUNCH 6
7
8 END
CAVE IN ROCK
CAVE-IN-ROCK STATE PARK
ELIZABETHTOWN
ROSICLARE
SHETLERVILLE
SPARKS HILL
KARBERS RIDGE
GROSS
EICHORN
CAOIZ
TOWER ROCK RECREATION AREA
HURRICANE IS
OHIO RIVER
SHAWNEE NATIONAL FOREST
ILLINOIS CENTRAL GULF RR
CARRSVILLE
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